Covenant University

28th INAUGURAL LECTURE

Safe Food for Sustainable Development of the Packets of Microorganisms Guided by Divine Essence

Solomon U. Oranusi

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The Chancellor, and Chairman Board of Regents of Covenant University, Dr. David O. Oyedepo; the Vice-President (Education), Living Faith Church Worldwide, Pastor (Mrs.) Faith A. Oyedepo; the Pro-Chancellor, Covenant University, Bishop David O. Abioye; the Secretary, Board of Regents/University Secretary, Covenant University, Pastor Adedeji Owojaiye, Esteemed members of the Board of Regents of Covenant University; the Vice-Chancellor, Professor Abiodun H. Adebayo; the Ag. Registrar, Mr. Emmanuel Igban; Principal Officers and Members of Covenant University Senate; Former Inaugural Lecturers present; Distinguished Faculty and Staff, Eminent Scholars; Special guests and invitees; Gentlemen of the Press; Kings and Queens in Hebron; Distinguished Ladies and Gentlemen.

1.0 PREAMBLE

To God be the glory for the opportunity of life granted me. I appreciate the Chancellor, the Pro-Chancellor, the Vice-Chancellor, and the University Management for the honour to stand before this great audience of intellectuals to present my inaugural lecture today. This inaugural lecture, which is the 28th in Covenant University, is the tenth from the College of Science and Technology, the third from the Department of Biological Sciences, and the second from the Microbiology programme. Listening to the past 27 inaugural lectures in this glorious chapel, one would wonder if any other area of study is left out of the numerous lectures and if any other lecture would ever be better than that of each speaker in each past inaugural lecture. Fortunately, the inaugural lecture platform is not a podium where speakers are called up for fantasy, and fictional conjunctures to overtly or covertly duplicate thought-forms. It is a platform to expouse and give account of personal adventure in one's field of endeavours.

In one of the social events in my secondary school days in the nineteen eighties (1980s), a debate was organised and I was asked to

speak on the topic "Military rule is better than democratic/civilian rule". The truth is that the converse of the topic is favoured by all rational thinking people; the general feeling will be that the proponents of democratic/civilian rule have won already. When I took the stage, some of my points put forward for the debate were that 'as a nation we have immature, and self-centered politicians trading tribalism, religious bigotry, nepotism, and careless political jingoism'. I concluded with the rider "ladies and gentlemen, with these few points of mine, I hope that you are all convinced and not confused that all the politicians in power at that point in time should be jailed and even executed to bring sanity to the nation". Mr. Vice-Chancellor, Sir, I do not know if my thinking then in the 1980s is right for the politicians of today. The military took over power shortly after that debate and proved to be worse than civilians. The fact was that by marshalling out my well-conjured points, and 'wowing' and wooing the juvenile judges and audience my team won the debate, and with that mentality, I applied to the Nigerian Defence Academy (NDA) three times; the story is for another day. Conjured points without experimental/scientific proof, as presented in the debate above will not pass for today's platform, but just as the general feeling was that the proponents of military rule have lost out already when democratic/civilian rule was the most acceptable and revered, the same would be if we consider the invisible microbial (microscopic organisms) world and the visible macroscopic world of all that you and I can see, accept, revere and believe in. In the debate "the microscopic invisible organisms rule/control man and the world **vs** man and all the visible things around him rule/control the world", it would be more acceptable to every right-thinking person to believe that man with all the technological advancements rules and controls his world; my lecture will be presenting the details of this debate.

It is a common quote that "the spiritual rules the physical", permit me Chancellor to further establish that the invisible microscopic microbial world around us rules the visible.

The Chancellor Sir, I am eternally grateful to God for specially preserving my life for this day. God in his infinite mercy used the topic of today's inaugural lecture to preserve my life when on Sunday 4th of March 2018 at about 4:30 pm, I left my apartment in the suites behind the University guesthouse. I was heading to the office to prepare for the week's lectures and work on a pending manuscript for publication. Before negotiating the bend, from the suites to the guesthouse, I heard a very clear voice that said "**your inaugural lecture write**" I ignored the voice, because I was not near the goalpost of delivering an inaugural lecture 5 years ago, however, just before the guesthouse gate, the voice spoke again "**your inaugural lecture write**" I had to stop under the Christmas tree right in front of the gate, picked a note from my bag and wrote down the topic as the voice dictated to me '**Food, Microbes, and Man: An Understanding that Man is but Packets (bunch) of Microorganisms on Safe Food and Guided by Divine Essence**', more of the information kept coming and I stood there and was writing. In a twinkle of an eye, a black Pathfinder jeep pulled down from the Engineering/Stadium area at top speed and lost control by the junction between ALDC and the guest house, the only thing that protected the vehicle from crashing into the guest house security post was the flowers and the gutter. Brethren, if not for the voice that stopped me, and the dictation I was taking on today's inaugural lecture, the few steps that I possibly would have taken could have placed me completely at the point of the crash, and made me the wedge for the vehicle; and with the level of damage done to the plants and the impact on the culvert, it would have been a different story. After all the efforts from the guest house manager, myself, and some other individuals to help the two young boys inside the vehicle, the voice did not stop speaking, I had to properly sit under the tree by the ATM machines in front of the guest house to take all the notes. The Chancellor Sir, I am standing here today simply because God has favoured me, and to Him alone be the glory.

The first inaugural lecture in the Department of Biological Sciences and from the Microbiology programme was delivered by Prof.

Louis O. Egwari on February 2014 with the title 'Microbial life in the presence of carbon and oxygen: consequences for man', it was part of the series of lectures for 2014/2015 session. His lecture was in the area of Medical Microbiology and he discussed the influence of microorganisms in nature. This inaugural lecture is the first from the Food Microbiology and Biotechnology option. I am equally very mindful of the fact that Prof. Odun Obembe from the Applied Biology and Biotechnology programme of the Department of Biological Sciences presented the 19th inaugural lecture of Covenant University and the second from the Department. The title of his lecture was 'subdue and dominate the earth: Plant biotechnology for sustainable development'. My research on microbiological and nutritional safety of food captured in the concept 'safe food' in today's lecture is so vital that it dominates all of the Sustainable Development Goals (SDGs), and it is expressly captured in SDG 12 and fulfilled in goals: 1,2,3,6-15 and 17 (Figure 1) and indirectly implied in goals 4, 5 and 16. The Chancellor Sir, a look at the SDGs simply reflects that all that humanity desires directly or indirectly is a safe food for all. The solution to all of the SDGs and safe food lies with the microorganisms and as soon as man is able to align with the microbes, all solutions will be provided.

Figure 1: Safe Food and the SDGs

The Chancellor Sir, this inaugural lecture will present my involvement in research with microorganisms in the field of food microbiology. The lecture 'Safe Food for Sustainable Development of the Packets of Microorganisms Guided by Divine Essence' will focus on the concept of food microbiology, food safety evaluation, development of microbiologically safe foods, food waste management and wealth creation.

1.0 INTRODUCTION

(*Epistemology of Microbiology - The Nature, Origin & Scope of Microbiology*)

Microbiology is a term coined from three words (*micro= small; bio= life; logos=study*) put together we have *small life study*. It is the science that deals with the study of all living organisms, both plants and animals, that are too small to be seen by the unaided eye, collectively known as 'microbes'. This includes bacteria, fungi (yeasts, molds), viruses, algae, protozoa, prions, and archaea (Figures 2a-d) (Microbiology Society, 2022).

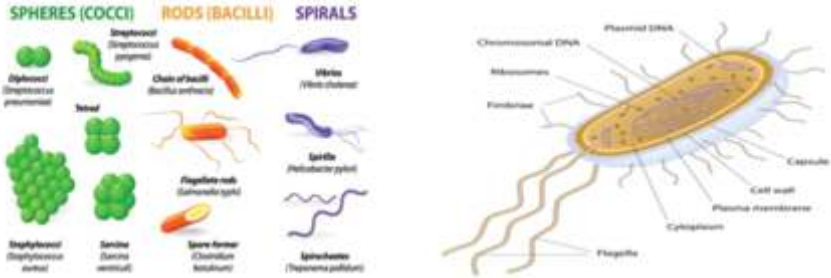

Figure 2a: Bacteria

Figure 2b: Fungi

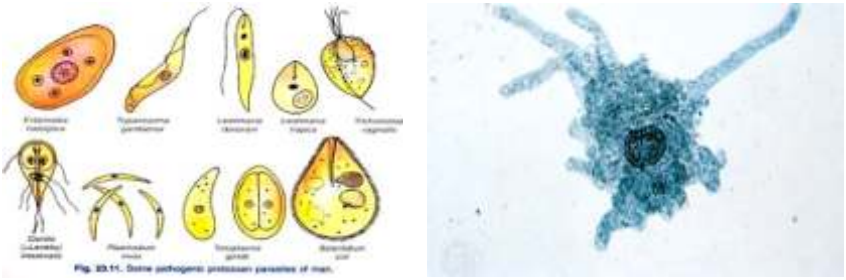

Figure 2c:Protozoa

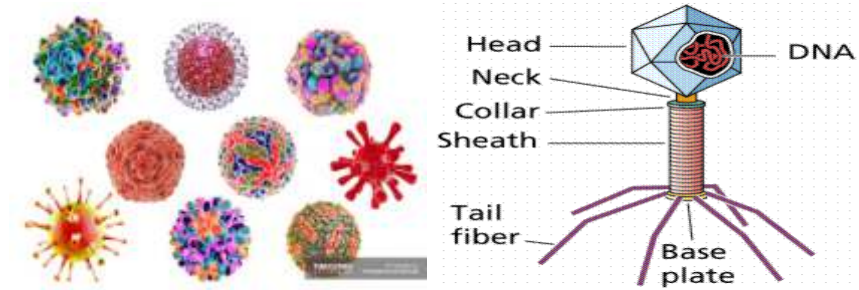

Figure 2d:Virus

Microorganisms are ubiquitous in nature i.e they can be found almost everywhere including in extreme environments where other living things cannot survive. Going by scientific account, microorganisms are the first living thing to always occupy any habitat thus they are the best indicator that any system (planet) is able to sustain life. By implication, microorganisms are older than man on earth. The conscious scientific study of microorganisms is, however, a more recent event that dates back to 1677 when Antoine Van Leeuwenhoek discovered the microscope (Lane, 2015).

The study of microorganisms progressed rapidly after the theory of abiogenesis (life originating from non-life) was disproved and the

Sources: Free use pictures of microorganisms, https://www.google.com/search?source=univ&tbm=isch&q=free+to+use+pictures+of+microorganisms

theory of biogenesis was accepted following the classical works of Francisco Redi 1626-1697, John Needhan 1713-1781, Lazzaro Spallanzani 1776, Theodor Schwan 1810 –1882, John Tyndall 1820-1893 and other proponents of biogenesis. The works of Louise Pasture 1822-1895 gave speed to the development of the study of microbiology (Aryal, 2019), and today, microbiology has two main branches:

i. Pure (Basic) microbiology
ii. Applied microbiology (*Madigan et al, 2015;* Talaro and Chess, 2021) (Figure 3)

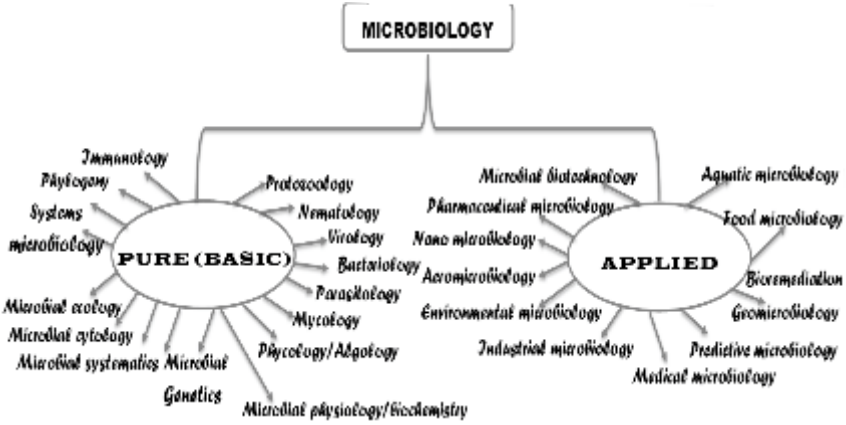

Figure 3: Branches of Microbiology

The pure or basic aspects of microbiology are concerned with the biology of microorganisms themselves, while the applied aspects are concerned with practical uses of microorganisms/ microbial products in problem-solving in industrial, medical, pharmaceutical, environmental, agricultural fields, etc.

The applications of microorganisms (applied aspect) often arise out of the basic study of microorganisms and basic studies often arise out of a need for the application of microorganisms, by implication, both aspects are intertwined.

Basic/pure fields of microbiology include:

1. Bacteriology: the scientific study of bacteria.
2. Mycology: the scientific study of fungi.
3. Virology: the scientific study of viruses.
4. Parasitology: the study of parasites (protists).
5. Protozoology: the study of protozoa.
6. Nematology: the study of nematodes.
7. Phycology/ Algology: the scientific study of algae.
8. Microbial genetics: the study of how genes are organised and regulated in microbes in relation to their cellular functions closely related to the field of molecular biology.
9. Immunology: deals with how the immune system protects the body from pathogens and the response of infectious agents.
10. Microbial biotechnology: the manipulation of microorganisms for better activity.
11. Microbial physiology and biochemistry- studies microbial metabolic capabilities, biosynthesis and chemical interactions/responses, and cell structure.
12. Microbial cytology: the study of microscopic and submicroscopic details of microorganisms.
13. Cellular microbiology: a discipline bridging microbiology and cell biology.
14. Evolutionary microbiology: the study of the evolution of microbes. This field can be subdivided into:

a. Microbial taxonomy: the naming and classification of microorganisms and
b. Microbial systematics: the study of the diversity and genetic relationship of microorganisms.

15. Generation microbiology: the study of those microorganisms that have the same characters as their parents.
16. Systems microbiology: a discipline bridging systems biology and microbiology.
17. Molecular microbiology: the study of the molecular principles of the physiological processes in microorganisms.
18. Phylogeny: the study of the genetic relationships between different organisms (*Madigan et al., 2015;* Talaro and Chess, 2021).

Applied aspects of microbiology are seen in every field of human endeavours and include but are not limited to the following areas:

1. Medical microbiology - deals with the pathogenic microbes and the role of microbes in human illnesses and diseases.
2. Pharmaceutical microbiology: the study of microorganisms that are related to the production of antibiotics, enzymes, vitamins, vaccines, and other pharmaceutical products that cause pharmaceutical contamination and spoiling.
3. Industrial microbiology- deals with the exploitation of microbes for use in industrial processes. Examples include industrial fermentation, brewing, and wastewater treatment. Closely linked to the biotechnology industry. This field also includes an important use of microorganisms to produce industrially useful products such as acids, alcohols, steroids, other solvents, enzymes.
4. Microbial biotechnology: the manipulation of microorganisms at the genetic and molecular level to generate useful products.
5. Food microbiology- deals with the use of microbes in food production, as a nutrient source, agents of spoilage, and diseases.
6. Dairy microbiology- deals with microorganisms in milk and milk products.
7. Agricultural microbiology- deals with agriculturally relevant microorganisms, the impact of microorganisms on agriculture in terms of biofertilizer, plant and animal pathogenic microbiology.
8. Veterinary microbiology: the study of the role of microbes in veterinary medicine or animal taxonomy.
9. Environmental microbiology: deals with the relationships between microorganisms and their habitat (biotic and abiotic), the study of the function and diversity of microbes in their natural environments. This field includes other branches of microbiology such as:
    a. Microbial ecology

b. Microbially mediated nutrient cycling
c. Geomicrobiology
d. Microbial diversity

10. Bioremediation: use of microorganisms to clean air, water and soils, in geological cycles in nature, pollutions, bioremediation.
11. Soil microbiology: the study of those microorganisms that are found in soil.
12. Aquatic /water microbiology. The study of those microorganisms that are found in water.
13. Aeromicrobiology (or air microbiology): The study of airborne microorganisms.
14. Petroleum microbiology. Deals with microorganisms in petroleum/mineral ore exploration.
15. Biotechnology: related to recombinant DNA technology or genetic engineering.
16. Astro microbiology (Space Microbiology or Exo microbiology): the study of microorganisms and their activities in outer space.
17. Biological agent: the study of those microorganisms, which are being used in weapon industries.
18. Nano microbiology: the study of those microscopic organisms at the nano level.
19. Predictive microbiology: the quantification of relations between controlling factors in foods and responses of pathogenic and spoilage microorganisms using mathematical modeling (Madigan *et al.,* 2015*;* Talaro and Chess, 2021)

3.0 FOOD MICROBIOLOGY: This deals with the use of microbes in food production, as a nutrient source, agents of spoilage, and diseases. Food microbiology deals with the relationship of microorganisms to food in health and diseases.

NOTE: water, soil, and air are indispensable factors in the cultivation, growth, processing, and utilization of food, milk/milk products are seen and consumed as food, therefore water, soil, air,

and milk/milk products are treated as component parts of food. Food microbiology involves the following:

- Food microbiology
- Dairy microbiology
- Aquatic microbiology
- Soil microbiology
- Aero microbiology
- Microbial Biotechnology
- Agricultural microbiology

A combination of aquatic, soil and surrounding atmosphere gives us Environmental microbiology

The adverse effects of the microbes from the environment and from the drinks/foods we eat give us sicknesses and diseases thus Medical microbiology and allied fields of Pharmaceutical microbiology.

Food microbiology is, therefore, a broad field of knowledge and as the saying goes "**man is what he eats**". Food microbiology holds the key to healthy and wealthy living. Remember **health is wealth**. A journey through food microbiology is, therefore, seen as a **journey through the do's and don'ts of living a healthy and wealthy life**.

My journey with microorganisms in food (food microbiology):
What motivated me to choose microbiology as a course and what stimulated my interest to specialize as a food microbiologist.

As a young boy, my mum often talked about germs and would always prevent/deny me from eating any food that fell to the floor/ground, irrespective of how dear such food was to me; this often created anger in me even when she replaced the fallen portion for me. My mum would beat me and force me to spit out every bit of the food if I stubbornly picked and ate food that fell off my hands. She was afraid and would scream 'germs will kill you, you will have stomach problem from germs'. She normally would sweep the house several times a day and mop and clean the house several times a week because of germs; this further compounded the problems

because my siblings and I must learn to do the cleaning to prevent germs that we had never seen. Mum would always flog me and my siblings for seeing dirts around the house and when she stepped on a grain of sand on the rubber carpet, which was in vogue then, you would be made to sweep immediately. I was determined to know what these germs that had caused me so much looked like. Why couldn't I see these germs and destroy them to have my way? I was determined that someday I will see these germs, hit them with a police baton, kill them and have my way.

The quest to study medicine abroad took me to Advanced level studies because a first degree or an A level was a requirement for some of the institutions that I would want to apply to. At my A level in the Federal School of Arts and Science, Suleja, Niger State, I attended a career talk and for the first time, I understood that the study of medicine would not give me an understanding of microorganisms as would the study of microbiology. I also got to know that the study of microbiology can make me work in every field of life, and with humans, plants, and animals. From that point, I completely signed off for this field of study.

Without informing my parents, I picked the next JAMB form and filled in for microbiology 1st, 2nd, and 3rd choice. The money sent for my registration for the lower 6 and upper 6 A level exams were used for my 1st and 2nd year's registrations in the university. Because of the uniform academic calendar, it was difficult for my parents to detect that I had left A levels. I was also not confident to tell my parents of my decision because they were waiting for the emergence of a medical doctor. In the course of the first degree, I observed that food microbiology is one field of study that tends to combine all the basic fields and most fields of applied microbiology. My quest to have a deep knowledge of this group of creatures was to be satisfied because as a food microbiologist I will get to study all the microbes in detail as they all contaminate food and have impacts on man, animals, and plants. My quest was further boosted when I read

literature and every food we eat as Nigerians/Africans were reported to have very high loads of microorganisms, in fact, our Nigerian foods are often described as grossly contaminated when compared to foods from advanced nations.

The situation is even more of a concern when you read articles from Nigerians and Africans, we tend to condemn our food more than others have done because all our findings are in tandem with what others have published earlier. As an undergraduate at the University of Nigeria, Nsukka, I tried to establish how many Nigerians die of food contamination; unfortunately, there was no data to this effect. If we are not dying of contaminated foods as reported, I reasoned that the microbes are contributing to our growth and status. With these in mind, I set out for my B. Sc research project. By the wisdom of my mentor Prof. Ezeogu Lewis, I was asked to work on a project that can be accommodated within the time allocated to B. Sc project work. Non-alcoholic drinks (soft drinks) are one of the most popular items on campus, and in the general society so I decided to check the microbial loads of popular non-alcoholic drinks sold in different parts of Nigeria. The result of this analysis showed that the drinks were microbiologically safe for human consumption. Chancellor Sir, the result of this work "Microbial contaminants of commercially bottled non-alcoholic drinks produced in Nigeria" was published in a SCOPUS listed journal (Oranusi *et al.,* 1994).

The second part of my success story as a food microbiologist is that my parents gave me all the needed support for my training. My dad was a notable pastor's warden and lay leader that enrolled in pastoral school at an advanced age after a humbling experience. As lay leaders and pastor's wardens, they were the decision-makers in the church; and any pastor posted to any parish was expected to obey these leaders in the church. In the 80s when several Pentecostal ministries and other unorthodox churches took the stage, the orthodox churches had to wake up to the reality of evangelism. Young vibrant graduates emerged as reverends in the orthodox

churches and some of them did not listen to the old lay leaders and pastor's warden, their voices were no longer relevant. My dad called me after my first degree while I was waiting on an uncle for a promised job. He said "if you must have a say in any field of life's endeavours and in any human setting, strive to get to the zenith of the training in your chosen field. Your mother and I will sacrifice anything we have as far as you are ready to progress". I maximized that open cheque. After the NYSC, I proceeded straight for my master's and Ph.D degrees in food microbiology.

My quest to understand why foods consumed by Nigerians are often reported as grossly contaminated led to the Hazard Analysis Critical Control Point (HACCP) evaluation of 'Kunun Zaki', a fermented beverage, at my master's degree. We discovered that the high level of contaminants was from fermentative organisms, the presence of non-fermenters and potential pathogens, however, we noted that they were of no consequence because the dominance of the fermenters and the fermentation environment made the food safe. Poor environmental and personal hygiene of the food handlers was, however, reported. The fermentative organisms hitherto reported as contaminants in our fermented foods are in reality good for the health as probiotics. Today, most Nigerian fermented foods are recommended for their probiotics components and these organisms are even packaged as supplements. Chancellor Sir, the findings from this study "Hazards and critical control points of Kunun-Zaki, a non-alcoholic beverage in Northern Nigeria" were also published in a SCOPUS listed journal (Oranusi *et al.*, 2003). Beyond the publication, using the HACCP model, this product Kunun Zaki with a normal shelf life of 6 -12 h, was improved and shelf life extended to 6 months under ambient room temperature. Further works on this product gave rise to the popular powdered kunun-mix, which is readily available in the market.

The contribution of microbes to the Nigerian population did not leave my psyche as I worked on nutritional anthropometry under the

title 'safety evaluation of foods consumed in boarding schools and selected families in Zaria' during my doctoral study. The microbial profiles of all the foods consumed by the study population over a period were analysed. The anthropometric indices (weight, height, chest circumference, head circumference, mid-arm circumference, and BMI) of these subjects were measured and analysed with regression/correlation and odds ratio cause and effect evaluations, to determine the microbial loads *vis-a-vis* the anthropometric indices relationships. The results showed that there was no relationship between the anthropometric indices and microbial loads of the foods. It was understood that it would take a long period of anyone's life study to establish this kind of relationship. The study also recorded that most of the foods were safe for consumption. Poor hygienic practices in both homes and the boarding schools were highlighted and duly communicated to the school authorities and the ministry of education, for improvement on the standards of food preparation for the students in the boarding houses. The findings from this work also highlighted 30% of underweight students; this could be a pointer to poor nutrition and underlying health challenges. More importantly, this finding highlighted the need for local anthropometric standards instead of the popular foreign standard. The publication of this work, Energy intake and anthropometry: a case study of families in Zaria, Nigeria (Oranusi *et al*., 2006, 2007), in a SCOPUS listed journal, attracted a collaboration with the demand for my contribution to a project that sought to document the anthropometric indices of Africans under different health conditions.

I wanted to have a sound knowledge of microorganisms, hence after my Ph.D programme, I left the field of food microbiology, registered for three years of training in medical microbiology at the Institute of Medical Laboratory Sciences, and was certified as a medical laboratory scientist specializing in bacteriology. I further registered and passed as a fellow of the Medical Laboratory Science Council specializing in parasitology. After about a decade in the medical

field, I wanted to experience the industrial field, I registered and passed as a public analyst specializing in water and food analysis. I also took some training in mycology. With these training and qualifications, people were getting worried about my long stay in training; I had to settle down for family life as a senior lecturer. I started my career as a medical laboratory scientist in ABUTH, my promotion and progression to the position of a professor came every 3 to 4 years. The Lord has been so good to me because right from my primary school I was always placed in a class with very brilliant and focused students, thus I naturally had to be a book worm to survive in the midst of such individuals. In this hall and connected online for this inaugural lecture are more than 12 professors who are either my primary, secondary, or university classmates. The implication is that what could be an average result in some classes will be a complete fail in the classes I found myself all through my training. God also blessed and connected me to very wonderful mentors, colleagues, and mentees (students) that are focused so the rigor of research and publications was a shared responsibility. Dear Kings and Queens in Hebron, the way to success is to build your capacity and have focused friends.

Chancellor Sir, before I establish the concept of my lecture today, permit me to briefly highlight the training schedule of a microbiologist and her contributions to the SDGs.

4.0 Contributions of Microbiology to SDG Knowledge in Solving Essential Societal Problems (*Pedagogical Tradition of Microbiology*)

The training of a microbiologist for a first degree, is a rigorous 4-6 years exercise depending on the field of microbiology; it involves over 80% practical work because the over forty fields of basic/applied specialization must register and sink at the first degree. The University entry qualification subjects include Biology, Chemistry, Physics, Mathematics and English Language. In the

training, courses are picked from the above-listed fields plus biochemistry, computer science, engineering, geography, business management etc. The microbiologist deals with lives - humans, animals and plants and sensitive parts of our environment, therefore extreme care and alertness are the watchwords in the training of a microbiologist because any mistake can lead to the death of the subject or a terrible catastrophe in the environment. A microbiologist is the health care provider you never see. The samples of blood, urine, faeces, swabs, biopsies, etc. taken from the patient are analysed by a microbiologist, thus without seeing the patient to ask questions, he/she is able to diagnose and tell the health conditions of the patient and suggest possible treatment options to the clinician and the pharmacist/nurses. Safe pharmaceuticals and personal care products are products that have gone through microbial quality control and standardization by the microbiologist.

The control of pandemic/epidemic situations just as we have for Coronavirus infection (COVID-19), is because microbiologists are at work to diagnose and even tell what kind of microorganisms we are dealing with. Before the establishment of microorganisms as the causative agents of human, animal and plant diseases, the gods, witches and wizards were blamed for everything. The development of vaccines, the discovery of antibiotics, and antimicrobial agents by microbiologists/alchemists is the miracle that has given meaning and colour to life, that man can live in good health and achieve his God-ordained tasks on earth free of microbial infestations/diseases, and free from the torments of gullible witch doctors, and priests/priestesses of gods and goddesses, that claim to have answers to the afflictions credited to the non-living gods that are the handworks of men. The 'orthodox' and 'unorthodox' pharma industries are major employers of labour worldwide.

The safe and nutritious foods from the industries are products of quality assurance/control from the microbiologist. Any carelessness on any product for human consumption can lead to mass death, thus the microbiologist is at the top of your safety '24/7'. Human

development and industrialization could only be achieved with the preservation of foods from microbial activities. Industrialization and global trade were only possible with the discovery of food preservation methods. The microbial food fermentation processes have made life worth living in terms of the quality, quantity, variety, and safety of foods and beverages at the disposal of man. The food industries are the largest employer of labour globally.

The breakthroughs in the field of agriculture are because plant and animal diseases are easily diagnosed by microbiologists; biotechnology and modern agriculture exploits are all products of microorganisms' manipulation. The explorations in the petrochemical industry are mostly by microbial activities, from petroleum prospecting through exploration and bioconversions. Microorganisms can produce and degrade virtually everything needed by man for existence, thus water purification/treatments, and waste management are completely within the domain of the microbiologist. There are no aspects of human, animal and plant lives that are not anchored directly or indirectly on microorganisms and the microbiologist hence every institution of man has quality control components. Every product designed for use by man ranging from the most sophisticated spacecraft to the common table salt must first pass the microbiology quality check/test or must not be used for anything.

The microbiologists are trained to have superb 'PR' because, in the course of our duty, you must work with all categories of persons, animals and plants and with everything in and around you. We are trained to relate with nature and to be confident and happy personalities with the consciousness that we are co-labourers with God. Microbes are very unstable and can pull surprises at any point, thus a microbiologist is trained to absorb shocks and surprises as part of life. For every reason with a good sense of understanding, I want to let this audience know that after GOD, the microbiologists will line up before any other.

Chancellor Sir, permit me at this juncture to establish the concept of today's inaugural lecture topic '**Safe food for sustainable development of the Packets of Microorganisms Guided by divine essence**'

Let me first establish the fact that man is a packet (bunch) of microorganisms.
As a food microbiologist and from the nutrition perspective, foods are classified based on the quantity of a specific nutritional value that they ~~it~~ contains as:

a. Carbohydrate food
b. Proteinaceous food
c. Fatty foods
d. Vitamin-rich foods
e. Mineral-rich food (MAAIF, 2015).

By this classification, a food is simply classified if it has the component in higher percentage eg carbohydrate foods have higher percentage of carbohydrate but also contain protein and fat and other components. Similarly, proteinaceous foods contain lots of carbohydrate and fat, while fatty foods contain carbohydrates and protein. From the chemistry and engineering perspective and by commercial value judgments an alloy, Gold, Metal etc. are not 100% pure; some are just 50 to 60% of what they are called. If a product is made up of 2, 3, or more components, the product more often than not is simply called by the name of the component with larger percentage especially if it is 50% or more of the entire product.

The microorganisms dominate the human system. Early reports claimed that man is made up of microbial cells 10 times more than the human cells (Savage,1977; Luckey, 1972). The most recent estimates of the number of human cells in the average human body [(a reference man 20-30 years of age, weighing 70 kilograms (155 pounds) and measuring 1.7 meters (5 feet, 6 inches) in height] is put at 30.0 trillion (3.0×10^{13}). The same individual should contain 3.8×10^{13} (about 31 trillion) bacterial cells in his body. This gives a ratio of

1.3:1 bacterial cells to human cells (Sender *et al*., 2016). The number of phages and viruses in man outnumber bacterial cells by at least an order of magnitude more (Reyes *et al.,* 2010). The simple meaning is that to every human cell there are 1.3 bacteria cell and more than 1.3 viral cells. Fungi and Archaea, have not been added. On a rough estimate, therefore, adding the bacteria, virus, fungi and archaea composition of an average man we have a minimum of 3 microbial cells to every human cell (i.e to every human cell there are three or more microbial cells), This amounts to ≥90 trillion microbial cells: 30 trillion human cells (≥9.0×10^{13} microbial cells to 3.0×10^{13} human cells). What are you then? The breath of life (divine essence) inside the pack of microbes is what makes the difference in us. The number of bacterial genes (assuming 1000 bacterial species in the gut with 2000 genes per species) is estimated to be 2,000,000 genes, 100 times the number of approximately 20,000 human genes, and research evidence confirms that even part of the human gene make-up is of microbial origin (Turnbaugh *et al.,* 2007). Gen 2:7 captures this vividly, we are just dust (not sand/earth) with the breath of life (divine essence). The major content of dust is microorganisms and at death, it is microbial dust unto dust and earth unto earth. After death and decomposition, it is heaps of microbes that are left not heaps of sand/earth. We must learn to give God all the glory because we are worth nothing without the divine essence - the spirit of God in us. Eccl. 3:30; Eccl. 12:7; Psalm 22:15; Psalm 30:9; Psalm 104:29; Job 17:16; Job 17:16; Job 30:19; Job 34:15; Isaiah 26:19; Isaiah 29:5 (all KJV).

5.0 WHAT IS SAFE FOOD?

Food is anything eaten, digested, and assimilated in the body for the purpose of obtaining nutrients (MAAIF, 2015). Safe food is food that is free from an unacceptable level of microbial load/microbial metabolites, that contains an adequate amount of nutrients in the right proportion and free from unacceptable chemicals, radiations, and physical contaminants, that may render such food injurious to health (WHO, 2020).

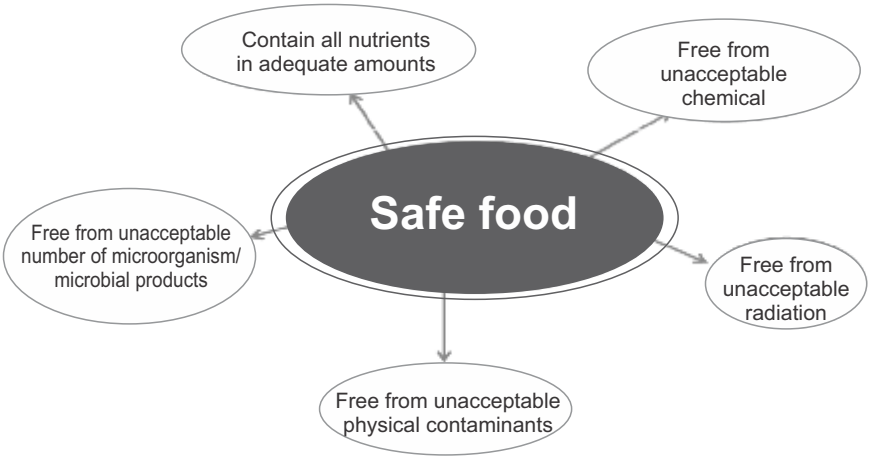

Figure 4: Concept of Safe Food

This concept of safe food is hinged on SDG 12, 'responsible consumption' of safe food and 'responsible production' of safe food. This is the key and live wire upon which man is able to fulfill all of the other SDGs.

Chancellor Sir, microbiologically and nutritionally unsafe foods are the leading causes of deaths worldwide, microbiologically unsafe foods are responsible for over 420,000 deaths annually (WHO, 2020), and result in the loss of 33 million healthy life years (disability-adjusted life year). US$110 billion is lost each year in productivity and medical expenses resulting from unsafe food in low- and middle-income countries and children under 5 years of age carry 40% of the foodborne disease burden, with 125 000 deaths every year. Over 45% of deaths among children, under 5 years of age are linked to nutritionally unsafe foods, while 1.9 billion adults are overweight or obese, and 462 million are underweight globally (WHO, 2021).

Microorganisms by reason of their small size have a very large surface area to volume ratio, thus very high metabolic activity. Because of the high metabolic activities of these microorganisms and the fewer number of real human cells that we are made of, eating

safe food to keep the immune system at top-notch cannot be compromised else the microorganisms will take over our bodies. All that man is doing is eating safe food, thus encouraging the immune system to be active to keep the microbial load in check. The moment a man is on unsafe food, the microbes take over and the man is riddled with infections/sicknesses, diseases and death. Poor nutrition normally leads to poor health; the environment of unsafe food lives us with a weakened immune system thus the microbes in us take over. Note also that the environment of sin drives out/withdraws the divine essence and divine immunity in us, we are left with our real content, the microbes (Acts 12: 21-23) thus the struggle with diverse sicknesses; diseases, and afflictions from microbes in us are not from the devil, witches or wizards. For this simple reason sin and poor nutrition produce the same effect (sicknesses and diseases), and it is only the divine presence in the pack of microbes 'that is the man' that makes the difference. Remove the divine out of the packet and you see that there is no man but microbes.

The Chancellor Sir, the association of food and microorganism (food microbiology) is as old as man is, or even older than man because microorganisms are deemed to have occupied the earth before the creation of man. God would not have created man without first putting in place the necessary foods to sustain man, Genesis 2:1-10. The man was the last to be created after every other thing including his food was put in place. Food and microbes being there before man could have been in association before man. Be that as it may, there seems to be no documentation of the exact time when man first became aware of the presence of microorganisms in food, however, the available evidence indicates that this knowledge preceded the establishment of microbiology as a science. The year 1677 marks the birth year of microbiology when Antoine Van Leeuwenhoek first examined microorganisms, he called them "animalcules" (Lane, 2015). It was after about 100 years that Microbiology was established as a science (Dilbaghi and Sharma, 2007). Indirect evidence of the association of microorganisms with food was provided by several experiments conducted by scientists to

explain the origin of microorganisms. The food-gathering and food-producing period prior to the establishment of microbiology as science are designated as the prescientific era. Food production involves domestication/ stock improvement of food animals and controlling food crops.

Food spoilage was an early concept because hunter-gatherers deal with food preservation of seasonally available food by drying/ salting/ smoking meats; dry storage of nuts and grains (Jay *et al*., 2005). It is presumed that the problems of spoilage and food poisoning were encountered early in this period. With the advent of prepared foods, the problems of disease transmission by foods and faster spoilage caused by improper storage made their appearance. Spoilage of prepared foods apparently dates back to about 6000 BC (Jay *et al.,* 2005). The practice of making pottery was brought to Western Europe about 5000 BC from the Near East. The first boiler pots are thought to have originated in the Near East about 8,000 years ago (Tite, 1999).

The Babylonians at around 7000 BC, were reported with the records of being the first to manufacture beer. The Sumerians are believed to have been the first great livestock breeders and dairymen at about 3000 BC and were among the first to make butter. Salted meats, fish, fat, dried skins, wheat, and barley are also known to have been associated with the Sumerian culture (Jay *et al.,* 2005; Andrews, 2018).

As early as 3000 BC, the Egyptians were reported to have used milk, butter, and cheese. Salt from the Dead Sea was reported to be used by the Jews in the preservation of various foods as early as 3000 BC and 1200 BC. Similarly, the Greeks and Chinese used salted fish in their diet, and the diet of the Romans is reported to have included pickled meats. The Assyrians were known to have prepared wines by 3500 BC (Andrews, 2018). By 1500 BC, the Babylonians and the Chinese prepared and consumed fermented sausages; olive and sesame oils were reportedly used for food preservation. By 1000 BC, the Romans were known to have used snow to pack prawns and other perishables and excelled in the preservation of meats other than beef (Jay *et al.,* 2005; Kapur, 2019).

During the Middle Ages, *Ergot* poisoning (caused by *Claviceps purpurea*), resulted in many deaths. Over 40,000 deaths due to ergot poisoning were recorded in France alone in AD 943 (Jay *et al.,* 2005). The year 1156 saw the emergence of meat butchers, and by 1248 the Swiss were concerned with marketable and nonmarketable meats. In 1276, a compulsory slaughter and inspection order was issued for public abattoirs in Augsburg. Although people were aware of quality attributes in meats by the thirteenth century, Athanasius *Kircher* 1602 -1680 was perhaps the first person to suggest the role of microorganisms in spoiling foods. In 1658, he examined decaying bodies, meat, milk, and other substances and saw what he referred to as "worms" invisible to the naked eye. Kircher's descriptions lacked precision, and his observations did not receive wide acceptance (Jay *et al.,* 2005; Weber.edu, 2022). Francisco Redi 1626 -1697, John Needhan 1713 -1781, Lazzaro Spallanzani 1776, Theodor Schwan 1810 -1882, John Tyndall 1820 -1893, contributed to the field of food microbiology in their experiments to disprove the doctrine of abiogenesis (the spontaneous generation of life which stipulates that life originates from non-living things and, by implication, suggesting that food spoilage is caused by the food materials transforming into maggots, etc.). The same may be said of Denis *Papin* (1647-1712) who invented the pressure cooker and Nicolas Appert (1749–1841) that discovered thermal canning. This, of course, was the beginning of canning as it is known and practiced today.

Louise Pasteur 1822-1895 was the first person to appreciate and understand the presence and role of microorganisms in food. He first coined the term "microbiology" for the study of organisms of microscopic size. He proposed the scientific principles of fermentation for the preservation of food, showed that microorganisms caused the souring of milk; he used heat for the first time to destroy undesirable organisms in wine, beer, and milk. This process is now known as pasteurization, a key factor in the food, brewery, and dairy industry today (Weber.edu, 2022).

It can be pictured that civilization could only progress when food preservation was accomplished. Fermented foods such as bread, alcoholic beverages, acid fermented vegetables grew out of attempts to "store" food. With civilization and industrialization, man moved from early methods of sun drying, smoking, salting, pickling to canning (thermal processing) and pasteurization based on the works of great microbiologists enumerated above. These developments can be said to be part of what culminated in the first industrial revolution. Post Industrial Revolution gave room to preservation methods such as sterilization, deep-freezing, freeze-drying (lyophilization), ionizing radiation (radioactive isotopes), modified atmosphere storage, etc.

6.0 MICROORGANISMS AND FOOD RELATIONSHIP

Understanding the relationship between food and microorganisms is important to maximize the merits and demerits inherent in the relationship and to utilize the full potentials of the microbes and foods for the benefit of man. Understanding the sources of microorganisms in food is important in order to:

i. develop methods to increase or decrease/control access of some microorganisms in the food;
ii. develop processing methods to maintain, increase, kill and reduce these microbes in foods to acceptable levels;
iii. determine the microbiological quality of foods; and
iv. set up microbiological standards and specifications of foods and food ingredients.

The relationships of microbes to food and man are in three-fold:

- They can cause food spoilage.
- They can cause foodborne illness.
- They can transform a food's properties in a beneficial way.

The nutritional/chemical composition of a food often defines the microbial activities associated with the food. This is because the microorganisms must as a necessity possess the right enzyme systems to be able to metabolize the food for survival.

1. They can cause food spoilage (food losses and food wastes)

Food losses/wastes caused by microorganisms can occur at different stages of the food supply chain including (a) Agricultural production; (b) Post-harvest handling and storage (c) Processing (d) Distribution (e) Consumption (Fig. 5). Food losses refer to the decrease in edible food mass at the production, postharvest and processing stages in the food supply chain, leading to insufficiency of edible food for human consumption (Parfitt *et al*., 2010; Thakali and MacRae, 2021). Food wastes are losses occurring at the end of the food chain retail and final consumption, which relates to retailers and consumers' behaviour (Parfitt *et al*., 2010). The concepts of "planned" non-food uses and "unplanned" non-food uses are terms used to better clarify the definitions of food losses and waste. Seen from the microbiological spoilage point of view, loses and wastes (unplanned non-food uses) in the food supply chain is mainly caused by microorganisms.

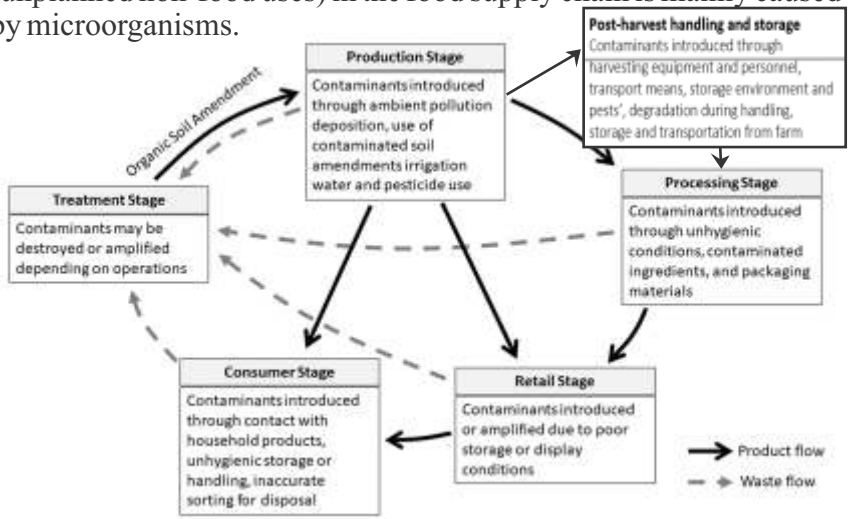

Figure 5: Food losses and food wastes
(Adapted from Thakali A. and. MacRae J.D 2021.

About a third of the food produced globally goes to waste each year which amounts to about 1.3 billion tons per year (FAO, 2011; Gustavsson *et al*., 2011; Thakali and MacRae, 2021). This inevitably means that the enormous amounts of the resources used in food

production, the water, energy, and material consumption required for the production, processing, storage, and transport of food, are used in vain; that is not productively used, and the greenhouse gas emissions caused by the production of food that gets lost or wasted are also emissions in vain (FAO, 2011; Pleissner, 2018). The U.S. Department of Agriculture estimated that 11.8 percent, or 15 million households, had problems providing enough food in 2017 (U.S. EPA, 2020). Figures 6 and 7 present the production volumes and losses in different regions.

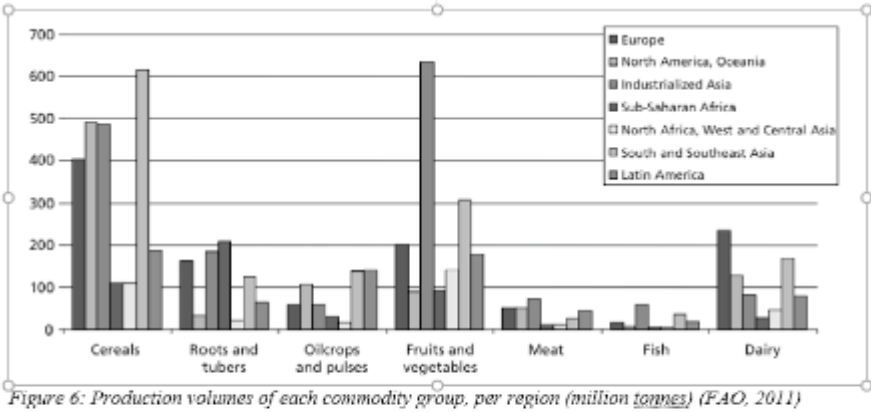

Figure 6: Production volumes of each commodity group, per region (million tonnes) (FAO, 2011)

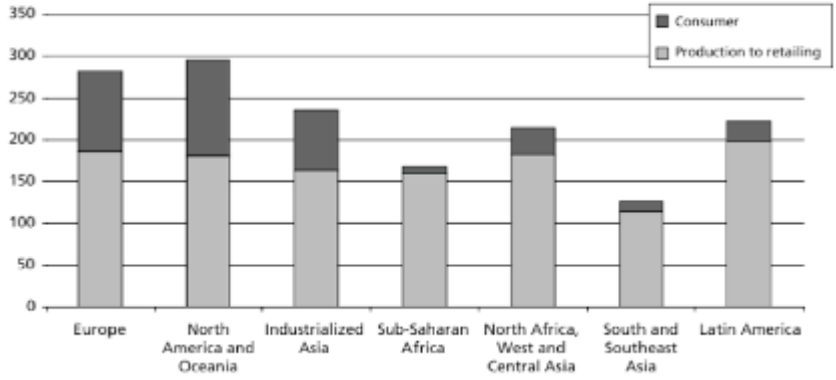

Figure 7: Per capita food losses and wastes (kg/year), at consumption and pre-consumption stages, in different regions (FAO, 2011)

Food waste or loss statistics provided above is measured only for products that are directed to human consumption, excluding feed wastes and losses due to microbial activities which are also known to be colossal (Kemboi *et al.,* 2020).

2. They can cause foodborne illnesses/diseases

Safe food emphasis is on the total quality of food, which means food should not only be nutritionally balanced but should also be microbiologically, chemically, and radiation safe. The spoilage of food and the presence of food poisoning organisms in food are very important from the point of food safety. The World Health Organisation statistics on foodborne disease burden due to microbial contamination is as presented in Figures 8a-e.

Figure 8a: Global foodborne disease burden
Source: WHO, 2020

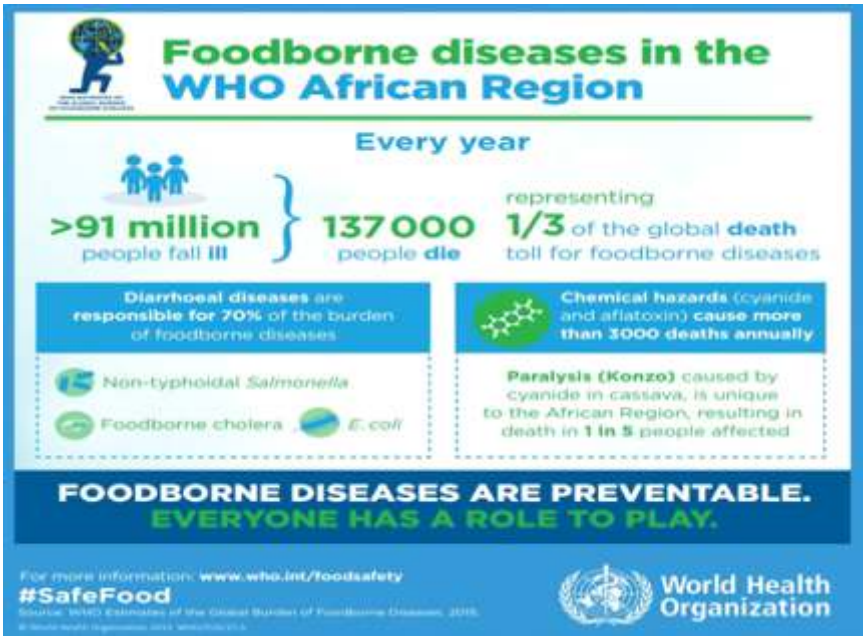

Figure 8b: Africa foodborne disease burden
Source: WHO, 2020

Figure 8c: Global foodborne diarrhoeal disease burden
Source: WHO, 2020

More than 200,000 persons die of food poisoning in Nigeria annually. It is quite common to wake up to the news of families being wiped out overnight after a meal. In recent years, Amala (yam flour meal) and cassava-based dishes have claimed several lives than all other foods combined.
In 2017, the Nigerian ministry of health revealed that food poisoning was responsible for up to 5,160 deaths; this has been linked to chronic diseases such as systemic failure and cancer (Food poisoning in Nigeria: Causes and Treatment. Federal Ministry of Health: Prevalence of food poisoning in Nigeria)

The Federal Ministry of Health identified the CAUSES OF FOOD POISONING IN NIGERIA to include:

1. Poor sanitation and hygiene in food preparation areas, including mega restaurants
2. Failure of regulatory agencies to enforce law and food hygiene guidelines
3. Insufficient washing of products such as vegetables and fruits before eating
4. Irrigation of farms and gardens with human wastewater
5. The use of pesticides and other agrochemicals beyond permissible limits
6. The use of an unhygienic food transport system to convey food from one point to another
7. The use of banned chemicals for food storage by hoarders and traders
8. The use of short-cut food processing methods by unscrupulous food processing agents and Companies

Figure 8d: Nigeria foodborne disease burden and causes
Source FMH, 2020

Figure 8e: Major causes of foodborne diseases
Source: WHO, 2020

3. They can transform a food's properties in a beneficial way:
Microorganisms have been involved in food production even before their existence was known to man. The conscious application of microorganisms in food production and the use of microorganisms as food are of tremendous benefits because it has added to food value in terms of:

i. Variety
ii. Acceptability
iii. Nutrient enhancement/diverse nutritional forms
iv. Nutrient availability
v. Preservation/shelf stability
vi. Detoxification
vii. Improved digestibility
viii. Enhanced flavour
ix. Cheap varieties etc.

In Nigeria, different foods are prepared via microbial activities (fermentation), these include:

a. Cereals
b. Tubers
c. Legumes
d. Milk-based foods (Obafemi *et al*., 2022)

Fermented cereals:

Ogi

Ogi is produced generally by steeping maize/sorghum/or millet grains in water for one to two days (fermentation), followed by wet milling and sieving through a screen mesh. The sieved material is allowed to sediment and ferment further, and it is marketed as wet cake. Microorganisms involved in ogi production include Lactobacillus species of lactic acid bacteria (*L. plantarum*), yeasts (*S. cerevisiae*), *Enterobacter cloacae* and *Corynebacterium.* The *Lactobacillus* species are known to have probiotics potential and the antibacterial activities of ogi liquor against some common diarrhoeal bacteria have been associated to its rich content of a

variety of lactic acid bacteria (Adisa and Enujiugh, 2020).

Kunun-zaki

The production of kunun-zaki involves the steeping of grains (millet, rice, sorghum) or ground nut, tiger nut, for fermentation, wet milling with spices (ginger, cloves and pepper), while sweet potatoes may be added. This is followed by wet sieving and partial gelatinization of the slurry; sugar may be added if no potatoes were included, before bottling. Lactic acid bacteria and yeasts are responsible for the fermentation which occurs briefly during steeping of the grains in water for 8 to 48 hours' period. Kunun-zaki is a refreshing drink consumed by both adult and children as appetizers, food supplement to quench thirst. It is usually served at social gatherings and used to entertain visitors (Oranusi *et al.,* 2003).

Burukutu

The preparation of burukutu involves fermenting sorghum grains by steeping in water overnight, draining off water, the grains are malted by spreading out on a mat or tray, covered with banana leaves and allowed to germinate. The grains are watered on alternate days during the germination processes, and turned over at intervals. The malted grains are sun dried and blended to powder. Garri and water are added to the mixture of the ground malt to serve as adjunct and give body to the product. The resulting mixture is allowed to ferment for two days after which it is boiled to obtain a cloudy alcoholic beverage. Predominant microorganisms involved in burukutu production include species of *Lactobacillus* lactic acids bacteria, yeasts and *Acetobacter* species of microorganism (Yusuf *et al.,* 2020).

Pito

Pito is a refreshing drink produced by steeping the cereal grains (maize, sorghum, or combinations of both) in water for two to three days' fermentation, followed with malting by stocking the grains in basket lined with moistened banana leaves for five days. The malted grains are wet-milled and boiled. The resulting mash is filtered

through a fine mesh, the filtrate thus obtained is allowed for overnight fermentation to assume a slightly sour flavour, after which it is boiled to concentrate. A starter from the previous brew is added to the cool concentrate and allowed to ferment overnight. It contains sugars and amino acids and has an alcoholic content of about 3%. Microorganisms responsible for Pito fermentation include species of Lactobacillus lactic acid bacteria, *Candida, Geotricum candidum* (Otunba *et al.,* 2021).
Local gins are produced from distillation of cereal/tuber-based alcohol fermentation via yeast *S. cerevisiae*

Fermented milk and dairy products:
Nono and Fura
Nono is a delicious and refreshing beverage prepared by pitching freshly drawn cow milk with the leftover nono as starter and then allowed to ferment for twenty-four hours at room temperature. During fermentation, some of the lactose are converted to the lactic acid. At the end of the fermentation period, the milk butter (kindirmo) is removed by churning for further use and the remaining sour milk is nono. The microorganisms involved in the fermentation process include species of lactic acid bacteria, Lactobacillus (*L. acidophilus* and *L. bulgaricus*), Lactococci species (*L. cremoni*, and *L. lactis*), *Streptococcus thermophiles, Leuconostoc* species, *Saccharomyces* species. Nono has yoghurt-like taste (sharp acid taste), and is, therefore, usually taken with sugar, and fura which is made up of millet flour moistened with water and compressed in balls and cooked for about twenty to forty minutes. Fura undergoes fermentation during storage. The cooked fura is crumbled in a bowl of nono (now called fura de nunu). It is a rich relaxing drink, an excellent source of protein, carbohydrate, rich in essential amino acids and a good source of calcium, phosphorus and vitamins (Confidence and Anyanwu, 2019).

Wara (Warankasi) is known as soft cheese amongst indigenous African consumers. Warankasi is a milk-based product that is fermented using an overnight pitch of warankasi. The fermented

cows' milk is curdled with the enzyme Papain or Calotropin (renin) obtained from the leaves of pawpaw (*Carica papaya*) or Sodom apple (*Calotropis procera*). The milk is gently heated in a pot over a wood fire. Following coagulation, the loose curd pieces are poured into small raffia baskets and allowed to drain. The microorganisms implicated include *Lactobacillus* strains of lactic acid bacteria, *Lactococcus* spp and *Streptococcus* spp (Ajibola *et al*., 2020).

Fermented root crops/Tubers:

Fufu

Fufu is made by steeping whole or cut peeled cassava roots in water to ferment for three to five days. During the steeping, lactic acid fermentation decreases the pH, softens the roots and helps to reduce the potentially toxic cyanogenic glycoside linamarin. The fermented tuber is sieved to remove the fibres. The Sievert (sieved mass) is allowed to sediment, dewatered and the cake is cooked and pounded/stirred and eaten with soup. The microorganisms implicated in fufu production include species of *Lactobacillus*, *Corynebacterium,* and *candida* (Nwachukwu *et al.,* 2017).

Garri

Garri is made from fermented, roasted fresh cassava tubers. The fresh cassava tubers are peeled, washed, and grated. The resulting pulp is put in a porous sack and pressed to dewater and ferment over a period of two to four days to remove hydrogen cyanide (HCN). The de-watered and fermented lump is pulverized, sieved and the resulting semi-dry fine pulp is roasted in a pan over fire. The grating, effluent expressing, pulverization, roasting, and the addition of palm oil as in yellow garri are adequate to reduce hydrogen cyanide (HCN) to a safe level.

Fermentation is mainly by species of *Leuconostoc, Corynebacterium,* yeasts and LAB (Ahaotu *et al*., 2017; Olopade *et al.,* 2014).

Other products of microbial activities from cassava and tubers include Lafun, Tapioca/Abacha, Amala.

Legume-based products:

I Iru (Dawadawa)
ii. Ogiri
iii. Okpiye
iv. Ugba
v. Owoh

Iru

The production of iru involves steeping seeds of *Pakia Biglobosa* (African locust bean) overnight in water, the de-hulled seeds are boiled for 2-4 hours. The seeds are washed, and fermented for 3-4 days. The resulting products are used as food condiment (Compaoré *et al*., 2020). Microorganisms in iru fermentation include *Bacillus subtilis*; *Micrococcus luteus, Lactobacillus salivarius, Staphylococcus aureus, Lactobacillus plantarum, Citrobacter freundii,* and *Streptococcus pyogenes.*

Ogiri

Ogiri can be made from the fermentation of the seeds of *Ricinus communis* (castor oil), *Citrullus vulgaris* (melon), *Telfairia occidentalis* (Fluted pumpkin), or *Vigna subterranea* (Bambara groundnut). The seeds from *R. communis* is boiled for 3-4 hours and de-hulled then mashed. The mashed seed is allowed to ferment for 3 to 4 days and used as condiment. *Bacillus subtilis, Lactobacillus fermenti, Citrobacter freundii*, *Staphylococcus* species are the microorganisms involved in ogiri fermentation (Chukwu *et al*., 2018).

Ugba

Ugba is produced from *Pentaclethra macrophylla* (African oil bean) seeds by boiling for 6-8 hours, the de-hulled seeds are washed and steeped in water overnight. The seeds are sliced to 0.2 - 0.4 cm thickness, washed, and drained thoroughly to remove excess water. The sliced seeds are fermented for 3 days and it is ready for consumption. Microorganisms in ugba fermentation include *Bacillus licheniformis, Bacillus sphaericus, Micrococcus luteus, Bacillus subtilis, Bacillus pumilus, Lactobacillus plantarum, Bacillus firmus, Staphylococcus saprophyticus* (Olasupo *et al.,*

2016).

Beverage-based products:

i. Emu
ii. Oguro
iii. All cocoa-based beverages
iv. All coffee-based beverages

Microorganisms used as food

Probiotics

Probiotics are defined as live microorganisms which when administered in adequate amounts confer a health benefit on the host (FAO/WHO, 2002). They are live nonpathogenic preparation administered to improve and restore the microbial balance of the gastrointestinal tract. Probiotics, as biological factors, control the gut microbiota and result in its progression. Probiotics are organisms which are generally regarded as safe (GRAS) and consumed without the risk of infections (Getahun *et al.,* 2016; Orsi and Zambrini, 2017). To be functional in the intestinal tracts, probiotics are expected to be viable and in a certain number. As such, the modes of delivery and production should be targeted towards maintaining the viability of the organisms after production and even during storage. Organisms that have been used as probiotics include:

a. Lactic acid bacteria - *Lactobacillus*
b. *Bifidobacterium*
c. A nonpathogenic *E. coli* strain (*E. coli* Nissle 1917)
d. *Saccharomyces boulardii*
e. *Clostridium butyricum*
f. *Streptococcus salivarius* subspecies *thermophilus*
g. Genetically engineered bacteria that secrete immunosuppressive substances such as interleukin-10 (IL-10) have been studied (Tiwari *et al.,* 2012)

Probiotics are commonly consumed as part of fermented foods with specially added active live cultures, such as in:

i. yogurt

ii. soy yogurt
iii. cheese
iv. dietary supplements and
v. fermented condiments listed above.

Probiotics may beneficially affect the host by augmenting its intestinal microbial population beyond the amount already existing, thus possibly inhibiting pathogens (Ansong, 2020).

Specific attributes that position an organism to be an effective probiotic include:

a. acid tolerance
b. bile tolerance
c. cell surface hydrophobicity
d. protoplast regeneration
e. antimicrobial activity
f. cholesterol removal
g. bile salt deconjugation
h. gut colonization
i. lactose removal
j. protease
k. amino peptidase activity (Sleator, 2015).

There has been an increase in recent years in the application of probiotic for the treatments of some diseases, and to alleviate the symptoms of many others. Diseases and ailments such as:

i. diarrhea
ii. pouchitis
iii. cancer
iv. ulcerative colitis
v. irritable bowel disease
vi. Mouth diseases and a host of others have experienced an increase in the use of certain probiotics bacteria to combat them (Oranusi *et al.,* 2014).

The complete mechanism of action of probiotics in disease management is not known, however, the major activity thus appears to be via:

a. colonization-competitive shielding off of pathogens
b. immune-modulations: Several research efforts have explained these activities to include improving gastrointestinal tract health via:
i. modifying gut pH
ii. antagonizing pathogens through production of antibacterial compounds
iii. competitive exclusions of pathogens at the binding and receptor sites
iv. enhancing the immune system
v. synthesizing and enhancing the bioavailability of nutrients
vi. competing for available nutrients
vii. reducing the symptoms of lactose intolerance
viii. decreasing the prevalence of allergy in susceptible individuals
ix. reducing risks of certain cancers through binding of deleterious mutagens and carcinogens (Oranusi *et al.,* 2014)

Single Cell Protein (SCP)

This is the cultivation of unicellular microorganisms as a direct source of human food. In order to manage the ever-increasing human population, it is imperative that new food sources be found in order that future generations are adequately fed.

A food source that is:

i. nutritionally complete
ii. requires a minimum of land
iii. requires a minimum of time and
iv. requires a minimum of cost to produce is highly desirable.

In addition to meeting these criteria, SCP can be produced on a variety of waste materials (Suman, 2015).

Among the overall advantages of SCP over plant and animal sources of proteins are the following:

a. Microorganisms have a very short generation time and can thus provide a rapid mass increase.

b. Microorganisms can be easily modified genetically to produce cells that bring about desirable results.
c. The protein content is high.
d. The production of SCP can be based on raw materials readily available in large quantities.
e. SCP production can be carried out in continuous culture and thus be independent of climatic changes.
f. Bacteria, yeasts, and molds can be grown on a wide variety of materials, including:
i. Food-processing wastes such as cheese whey and brewery, potato processing, cannery, and coffee wastes and wastes from our local products like Ogi, kunun, iru, ogiri etc.
ii. Industrial wastes such as sulfite liquor in the paper industry and combustion gases.
iii. Cellulosic wastes including bagasse, newsprint mill, and barley straw.
g. SCP Products can be used directly as a protein source in animal feed formulations, thereby freeing animal feed, such as corn, for human consumption, or they may be used as a protein source or food ingredient for human food.
h. In the case of animal feed or feed supplements, the dried cells may be used without further processing.
i. Microorganisms are relatively high in nitrogen, carbohydrates, lipids, minerals and are excellent sources of B vitamins.

There are draw backs to the effective use of single cell protein, these include:

i. the endotoxins.
ii. the high nucleic acid contents caused by an accumulation of uric acid, which is sparingly soluble in plasma. These compounds can be reduced to levels below 2% by techniques such as:
a. acid precipitation
b. acid or alkaline hydrolysis or
c. use of endogenous and bovine pancreatic RNAses (Sorour *et al*., 2021).

Other Products of microorganisms that are of importance to man

Product / Activity Products	Examples
1. Amino acids	L-glutamic acid, L-lysine
2. Antibiotics	Streptomycin, penicillin, tetracyclines, polymyxin
3. Beverages	Wine, beer, distilled beverages
4. Biodegradable plastics	β-polyhydroxybutyrate
5. Enzymes	Amylase, proteases, pectinases, invertase, cellulose
6. Flavouring agents	Monosodium glutamate, nucleotides
7. Foods	Cheese, pickles, yoghurt, bread, vinegar
8. Gases	CO_2, H_2, CH_4
9. Organic acids	Lactic, citric, acetic, butyric, fumaric
10. Organic solvents	Acetone, ethanol, butanol, amyl alcohol
11. Miscellaneous	Glycerol, fats, steroids, gibberellins
12. Vitamins	B_{12}, riboflavin A
13. Recombinant proteins	Insulin, interferon, subunit vaccines
14. Substrates	A wide range of compounds used for chemical syntheses of valuable products. Cells/Biomass
15. Biomass	Food and feed yeast, other organisms used as single cell protein (SCP)
16. Cells	Biofertilizers, biocontrol agents, bacterial insecticides, mycorrhyzae
17. Vaccines	A variety of viral and bacterial vaccines Activities
18. Biotransformation	Steroids, antibiotics D-sorbitol.
19. Degradation	Disposal of biological and industrial wastes, detoxification of toxic compounds, petroleum.
20. Solubilization/ accumulation	Improved recovery of oil and metals, discovery of new oil reserves, removal of toxic metals.

7.0 SURVEY OF MICROORGANISMS IN FOOD

Microorganisms get into foods from sources with which food comes into contact from the time of production until the time of consumption (Thakali and MacRae, 2021), these sources include but are not limited to:

1. Natural sources of plant origin– the surface of the fruits, vegetables, and grains and the pores in some tubers (radishes and onions)
2. Natural sources of animal origin – skin, hair, feathers, gastrointestinal tract, respiratory tract, and milk ducts in udders of milk
3. Natural microflora exists in ecological balance with their hosts and their types and levels vary greatly with the type of plants and animals

Food can be contaminated with different types of microorganisms coming from outside sources such as:

I. Air:- Microorganisms are present in dust in the air, they do not grow in dust but are transient and variable depending upon the environment. Their level is controlled by the degree of humidity, size and level of dust particles, temperature, and air velocity, and resistance of microorganisms to drying. Dry air with low dust content and a higher temperature have a low microbial level, spores of *Bacillus spp., Clostridium spp.,* mold, and Gram-positive bacteria (*Micrococcus spp and Sarcina*).

ii. Soil:- Soil contains several varieties of microorganisms, they can multiply in soil, their numbers can be very high. Moulds, yeasts, and bacteria genera (*Enterobacter, Pseudomonas, Proteus, Micrococcus, Enterococcus, Bacillus,* and *Clostridium*) can get into foods from the soil. Soil contaminated with fecal materials can be a source of enteric pathogenic bacteria. Sediments, where fish and marine foods are harvested, can also be a source of microorganisms in those foods.

iii. Sewage:- sewage when used as fertilizer in crops can contaminate food with microorganisms such as enteropathogenic bacteria and viruses. Sewage is a major concern with organically grown foods and there are many imported fruits and vegetables where untreated sewage may be used as fertilizers.

iv. Water:- used to produce, process, and in some cases store foods; used for irrigation of crops, drinking by food animals, raising fishery and marine products; washing foods, processing foods, pasteurization, canning, and cooling of heated foods; washing, and sanitation of equipment, processing and transportation facilities. Water is used as an ingredient in many processed foods thus can greatly influence the microbial quality of foods.

v. Humans:- between production and consumption, foods come in contact with different people handling the foods, not only the people working in food processing plants, but those handling foods at restaurants, catering services, retail stores, and at home. Sources of pathogenic microorganisms in food that later cause foodborne diseases could be improperly cleaned hands, lack of aesthetic sense and personal hygiene. Dirty clothes, and hair can be major sources of microbial contamination in foods. Pathogens such as *Staphylococcus aureus*. *Salmonella spp, Shigella spp,* Pathogenic *E. Coli,* and Hepatitis A virus can be acquired from human sources.

vi. Food ingredients:- many prepared or fabricated food ingredients or additives included in different quantities can be a source of both spoilage and pathogenic microorganisms, various spices can possess very high populations of mold and bacterial spores, starch, sugar, and flour can have spores of thermophilic bacteria.

vii. Equipment:- a wide variety of equipment is used in the harvesting, transportation, processing, and storage of foods. Microorganisms from the air, raw foods, water, and personnel

can get into the equipment and contaminate foods. Depending on the environment and time, microbes can multiply from a low initial population to reach a high level, and contaminate large volumes of foods processing used continuously for a long period of time. Microorganisms present initially can multiply and act as a continuous source of contamination in the product. Small parts, inaccessible sections, and certain materials may not be efficiently cleaned and sanitized, therefore, can serve as sources of both pathogenic and spoilage microorganisms in food. Small equipment such as cutting boards, knives, spoons due to improper cleaning can be a source of cross-contamination. *Salmonella, Listeria, Escherichia, Enterococcus, Micrococcus, Pseudomonas, Lactobacillus, Listeria,* and yeasts and moulds can get into food from equipment.

viii. Packaging materials:- Many types of packaging materials are used in food. Since they are used in the products ready for consumption, and in some cases without further heating, proper microbiological standards (or specifications) for packaging materials are necessary.

ix. Unhygienic food transport system used to convey food from one point to another is a veritable source of food contamination, specifically where the means of transportation is for general purpose use.

x. Insects/rodents:- By their feeding habits they visit several contaminated sites including feaces and animal droppings, and deposit the microorganisms picked from these sites on the food.

Microbial types and their levels from these sources getting into foods vary widely and depend upon the degree of sanitation used during the handling of foods.

Chancellor Sir, permit me to digress a little; food is a major aspect of human culture and specifically religion. Culture is the driving

force of human existence. The microbial processing of food items gives each region of the world her unique identity and thus food microbiology is the basic issue in driving human existence. The major thing that defines a people is their food culture and mostly it is the microbially produced foods. Another strong aspect of human culture is their dressing and the materials from which these dresses are made, these materials are strictly defined by the microbial involvement in their production. Trade is an aspect that has united humanity. You can only trade microbiologically acceptable goods. To date, most products from my country Nigeria and the African continent cannot make the international trade due mostly to poor microbiological quality. The issue of food items and several other manufactured goods abandoned and littering our borders quickly come to mind because these products meant for export do not meet microbiological export standards. This is just to buttress the fact that the entirety of human life revolves around microorganisms and safe food.

8.0 FOOD SAFETY AND QUALITY CONTROL

Food Safety and Quality Control: Is aimed at making sure 'foods' that are meant for human, 'animal feed, and even plants fertilizer/manure' are safe (free of pathogens, free from deleterious chemicals, radiation, and physical contaminants, and contain the adequate amount and proportion of nutrients) and have a long as possible shelf-life (i.e. reduced microbial load to decrease spoilage) (WHO, 2013; FAO.org)

There are four main quality and safety concerns associated with foods and drinks which the microbiologist helps to address: microbiological concerns, physical contaminant concerns, chemical concerns, and radiation concerns.

(i) Microbiological Contamination

Controls to microbes are best implemented at the control/critical control points of contamination:

Food animals and plants

Effective animal husbandry, testing animals and birds for pathogens, and culling the carriers will be important in reducing incidence in foods. Using good quality water during slaughter, de-feathering, removing digestive and respiratory organs, proper sanitation during processing help to keep the microbial quantity at desirable levels. Proper cleaning of udder prior to milking, immediate cooling of milk after milking reduces microbial contamination and proliferation. Fish and marine products should be harvested from non-polluted and recommended water. Carcasses and plant materials should be stored at proper temperatures to prevent further contamination and microbial growth. Prepared and cooked foods should be stored separately from raw foods and unprepared vegetables to reduce the risk of cross-contamination. If this is not possible, raw food and unprepared vegetables should always be stored at the base of the refrigerator. Keeping stored foods covered prevent animals and insects from entering the food room. To multiply, microorganisms require food, warmth, moisture, and time. By removing one or more of these criteria the growth of microorganisms can be slowed or even stopped. Therefore, foods should be stored at safe temperatures (either cold below 8°C or hot above 63°C); effective storage also prevents moulds growth and mycotoxin formation (WHO, 2020; Khan and Rahman, 2021).

Air

Microbial contamination in the air can be reduced by: removing the potential sources, controlling dust particles in the air (using filtered air), using positive air pressure, reducing the humidity level, and installing UV light.

Soil

Removal of soil (and sediments) from produce after harvesting, and avoiding soil contamination from sewage, use of right concentration of chemicals and fertilizers, effective treatment of soil, will help to reduce microorganisms and contaminants in foods.

Sewage

Not to use sewage as fertilizers, or should be efficiently treated to kill the pathogens. Washing foods following harvesting is important to reduce microbial contamination of food.

Water

Wastewater can be recycled for irrigation after effective treatment; chlorine-treated potable water should be used in processing, washing, sanitation, and as an ingredient. Although potable water does not contain coliforms and pathogens, it can contain other bacteria capable of causing food spoilage such as *Pseudomonas, Alcaligenes,* and *Flavobacterium.* Improperly treated water can contain pathogen and spoilage microorganisms and this must be prevented.

Humans

To help keep food contamination from man at desirable level, proper and frequent handwashing, particularly after using the toilet, handling raw foods, handling refuse, picking/blowing the nose, touching/combing the hair, and after smoking, keeping cuts, boils, etc., covered with a waterproof dressing (preferably coloured), and to avoid handling food if suffering from symptoms of diarrhoea or vomiting are very essential. Good personal hygiene should be maintained, basic training on food safety measures is very important.

Food Ingredients

Ingredients should be produced under sanitary conditions and given antimicrobial treatments. Setting up acceptable microbial specifications for the ingredients will be important in reducing microorganisms in foods from this source.

Equipment

Proper cleaning, sanitation, and storage of equipment, use of standard equipment, are important to keep food preparation areas

and utensils clean.

Packaging materials
Proper microbiological standards (or specifications) for packaging materials are necessary since they are used in the products ready for consumption and in some cases without further heating.

(ii) Physical Contamination

Physical contamination can occur at any stage of the food chain and therefore all reasonable precautions must be taken to prevent this type of contamination. Examples of physical contamination include:
Pieces of machinery that fall into food during manufacture. Most manufacturers protect against this type of contamination by installing metal detectors on the production lines that reject food if anything metallic is present.
Stones, pips, bones, twigs, pieces of shell, and other foreign objects can enter food during handling so care must be taken to adhere to good food handling practices (e.g. not wearing jewelry or smoking in a food room).

(iii) Chemical Contamination

Chemicals, including pesticides, bleach, and other cleaning materials can contaminate food if not used carefully. Cleaning fluids should be stored separately from foods to prevent tainting and contamination if there is a spillage. Mycotoxins are major chemical contaminants in food. Effective harvesting, storage, and GMP/HACCP measures can help the control of mycotoxins

Strategies for enforcing Food Quality

1. Education & Training: From primary through secondary school education, hygiene practices
   and basic household culture must be revived. Practical

agriculture and home economics were the norms in our schools before now, these have to be revived. Education and training for food handlers on good manufacturing practices should be a condition for licensing food service providers.

2. Inspection of facilities & operations: Sanitary and environmental officers that are field-based and not office-based should be revived. Inspection of foodservice facilities, environment, and personnel, inspection of abattoirs and food animals for slaughter, inspection of market places and private homes used for manufacturing for compliance with standards will help in controlling microbiological concerns.
3. Microbiological testing: regular testing of products at different stages of processing and end-product analysis at the point of production and at retail outlets are measures that help in safety and quality checks.
4. Hazard Analysis Critical Control Point (HACCP) System

HACCP System: Used in Controlling Microbiological Hazards in Industrial Processing of Food

- It is a simple and effective way to ensure food safety.
- It allows manufacturers to predict risks to food safety and prevent them before they happen.
- HACCP takes into consideration:
- Factors that contribute to most outbreaks.
- Risks assessment techniques to identify and prioritize hazards.
- HACCP is a protective concept.
- The technique assures food safety from harvest to consumption.

HACCP components:
(1) Assessing hazards
(2) Identifying Critical Control Points (CCPs)
(3) Setting up procedures for CCPs
(4) Monitoring CCPs
(5) Taking corrective action

(6) Setting up a record-keeping system and
(7) Verifying the system is working.
The HACCP is an evaluation system to:

i. Identify
ii. Monitor
iii. Control contaminations risks in foodservice establishments (FDA, 2017).

Regulatory Agencies in the Food Industry must wake up to their responsibilities. A number of government agencies are involved in the enforcement of laws and regulations that affect food industries in keeping with the criteria: NAFDAC, SON, IPAN, NIFST FDA, USDA, EPA, OSHA, etc.

9.0 MY RESEARCH CONTRIBUTIONS

Chancellor Sir, my contributions to knowledge are in the areas of food safety (microbiological and nutritional safety) using the Hazards Analysis and critical control points (HACCP):

a. microbiological safety
b. nutritional safety and
c. Mycotoxin safety as it relates to:
   i. Beverages
   ii. Food Condiments
   iii. Ready-to-Eat Foods/ Street Vended Foods
   iv. Fruits and Fruit Juices
   v. Fresh/Raw Foods
   vi. Water and Drinks and
   vii. Food Waste Management

Evaluation for food safety indicators is achieved at three major points of the food processing chain:

1. At the point of selecting the raw materials
2. During the production/at the food processing establishment
3. At the consumer level/during retail and storage/consumption

My research endeavours focus mainly on establishing microbial

safety and nutrition safety of foods at the consumer level because at this stage, safety concerns associated with the raw materials are expected to have been addressed and the domineering influence of the manufacturer in the production/processing environment is ruled out. Thus, the exact quality of what goes into the consumer is obtained. At the level of the consumer, the quality of food is an interplay of the food quality released from the manufacturer, the quality of the storage process at retail, and what the consumer could contribute that will affect quality. In my quest to determine the safety level of foods consumed by Nigerians, several beverages, food condiments, cooked foods, fruits and fruit juices, fresh/raw foods, formulated foods, and drinks and water were analysed for bacteria, fungi, parasites, mycotoxins, and nutrition safety. Our findings revealed that most of our foods are of a tolerable standard but not acceptable standard, thus often short of the microbiological standard specification. However, as opposed to the popular belief that our foods are microbiologically grossly contaminated, and nutritionally unsafe, our foods are mostly fermented foods and from mixed fermentation. The fermentative organisms and flavour-enhancing organisms found in our foods are mostly lactobacilli and Bacillus spp and most of them are today "generally regarded as safe organism-GRAS" and some of them are today packaged as food supplements/functional foods as probiotics. Provided that there is no fermentation failure and that foods are prepared in our own local way of intense cooking, the major challenge is environmental sanitation and personal hygiene problems that can be addressed by education and training if we are ready. Human foods are not sterile, thus the isolation of microbial contaminants in food is not the basis for judging the food as microbiologically unsafe. Safety of food is a function of the levels of pathogens/potential pathogens and or their metabolites amongst the natural contaminants isolated (HPA, 2009).

Highlights of some of my investigations and contribution to knowledge

9.1 Beverages

Non-alcoholic beverages are highly prone to microbial contamination (Magar, 2021). The economic downturn in Nigeria has led to an outright ban on the import of the raw materials traditionally used for the production of various beverages, including non-alcoholic beverages. This has led to the importation of all manner of drinks, the use of local and unconventional raw materials for the purpose (Ogbonna & Obi, 1991), and changes in production practice, product quality, and shelf-life. There is, therefore, the need for constant monitoring of beverages for safety at the consumer level. We examined the microbiological profile of the entire spectrum of non-alcoholic beverages marketed in Nigeria. Oranusi, Ezeogu, and Okolo (1994) examined the microbial contaminants of commercially bottled non-alcoholic drinks produced in Nigeria.

Table 1. Rates of microbial isolation from the different groups of non-alcoholic beverages examined

Microbial genus	Occurrence (%)				
	Malt	Cola	Orange	Soda	Lemon/Miscellaneous
Bacillus	9	36	18	27	9
Lactobacillus	25	0	37	25	12
Pediococcus	–	100	–	–	–
Staphylococcus	–	100	–	–	–
Micrococcus	–	–	100	–	–
Saccharomyces	–	–	40	60	–
Aspergillus	–	–	–	100	–
Totals*	10 (33)	26 (20)	26 (66)	32 (75)	6.5 (29)
pH range	5.1 to 5.5	2.9 to 3.5	3.3 to 3.7	3.4 to 3.7	3.4 to 3.7

* Values represent the total rates of isolation of microbial contaminants from the different groups of beverages followed, in parentheses, by the percentage of non-alcoholic drinks within each category giving positive microbial cultures.

The organisms isolated from the drinks were mainly saprophytic non-pathogenic species of Bacillus, *Lactobacillus, Pediococcus, Staphylococcus epidermidis, Micrococcus, Saccharomyces, and Aspergillus niger* (Table 1). The microbial level was satisfactory, the safety of these products was attributed to the very low pH (2-5) and high sugar contents which thus raises a concern about their nutritional safety. Foods of very low acidity and high sugar contents are obviously not recommended.

Oranusi, Umoh, and Kwaga (2003), worked on the hazards and critical control points of kunun-zaki, a non-alcoholic beverage in Northern Nigeria (Table 2),

Table 2. Mean and range of bacterial count of vended Kunun-zaki in Zaria, Nigeria

Procedure	Samples/counts $\log_{10}$ cfu ml^{-1}		
	Bulk $n = 20$	PVC $n = 130$	Bottled $n = 90$
Total aerobic count			
Mean	6.40^a	6.18^a	5.99^b
Range	4.18–8.79	4.53–6.62	4.65–6.51
Staphylococcal count			
Mean	2.86^a	2.66^a	1.83^b
Range	1.90–3.40	1.78–3.00	1.60–2.30
Coliform count			
Mean	2.18^a	3.56^b	3.20^b
Range	1.60–2.60	1.70–4.26	1.90–3.60
Bacillus count			
Mean	4.00^a	3.72^b	3.00^b
Range	2.34–4.61	2.30–4.32	2.15–3.40

n = No. of samples tested.
Means in rows with the same superscript (a,b) are not significantly different.
LSD $\alpha = 0.05$.
PVC = polyvinylchloride.

We observed that though the level of microbial counts was within the tolerable limit, the presence of coliforms, *S. aureus*, and *B. cereus*; the preparation of products in a highly contaminated environment and the holding of products at ambient temperature for sale over a long period could be risky. Education of producers on the hazards, critical control points, and the importance of a hygienic environment is imperative. The control measures and monitoring procedures for kunun-zaki preparation were suggested. Coliforms were isolated at counts $\log_{10}$ 2.18 – 3.56, indicating contamination from water or the raw materials. The bottled products had lower levels of contamination compared to bulk and cellophane packaged products. As noted earlier, beyond the publication, using the HACCP model, this product Kunun-zaki with a normal shelf life of 6 -12 h, was improved and shelf life extended to 6 months under ambient room temperature. Further works on this product gave the popular powdered kunun-mix, which is readily available in the market.

Oranusi and Anosike (2018) carried out an assessment of microbiological and chemical qualities of selected cocoa, tea, and coffee brands in Nigerian markets (Table 3).

Table 3. Mean total microbial counts (cfu/g) for Cocoa, Tea, and Coffee samples

	Cocoa					Tea				Coffee		
SC	TAPC	TFC	SAC	TCC	SC	TAPC	TFC	SAC	SC	TAPC	TFC	
C1	1.5×10⁶/0.00	5.0×10⁴/0.00	<1.0		T1	8.8×10⁶/0.00	5.0×10⁴/0.00	4.0×10⁴/0.00	CF1	1.5×10⁶/0.00	5.0×10⁴/0.00	
C2	2.7×10⁶/0.00	1.0×10⁵/0.00	7.0×10⁴/2.00	1.2×10⁶/0.00	T2	1.1×10⁶/0.00	4.0×10⁴/0.00	-	CF2	9.5×10⁵/0.00	2.7×10⁴/0.00	
C3	1.5×10⁶/0.00	5.0×10⁴/0.00	<1.0	1.5×10⁶/0.00	T3	1.1×10⁶/0.00	3.0×10⁴/0.00		CF3	1.5×10⁶/0.00	5.0×10⁴/0.00	
C4	2.5×10⁶/0.00	2.5×10⁵/0.00	<1.0	-	T4	6.5×10⁶/0.00	4.0×10⁴/0.00	2.7×10⁴/0.00	CF4	2.0×10⁶/0.00	2.7×10⁵/0.00	
C5	2.0×10⁶/0.00	2.2×10⁵/0.00	<1.0	-	T5	1.5×10⁶/0.00	4.5×10⁴/0.00	-	CF5	2.2×10⁶/0.00	2.0×10⁵/0.00	
C6	1.8×10⁶/0.00	3.1×10⁴/0.00	<1.0		T6	2.3×10⁶/0.00	2.4×10⁴/0.00					
C7	2.5×10⁶/0.00	5.5×10⁵/0.00	1.0×10⁴/2.00	4.5×10⁶/0.00	T7	1.7×10⁶/0.00	2.8×10⁴/0.00	-				
C8	1.7×10⁶/0.00	3.1×10⁴/0.00	2.0×10⁴/2.00	2.0×10⁶/0.00	T8	2.3×10⁶/0.00	5.1×10⁴/0.00					
C9	2.0×10⁶/0.00	2.5×10⁵/0.00	-	-	T9	2.2×10⁶/0.00	2.0×10⁴/0.00	-				
C10	1.7×10⁶/0.00	3.0×10⁴/0.00	-	1.0×10⁶/0.00	T10	1.7×10⁶/0.00	2.7×10⁴/0.00	<10				

Key: SC= sample code; TAPC= Total aerobic plate count; SAC= *S. aureus* count; TCC= Coliform count; TFC= Fungal Count; C Cocoa products, T Tea products CF Coffee products, — No Bacterial Growth

We reported that the mean TAPC and fungal counts for the cocoa, coffee, and tea were not significantly ($p<0.05$) different from standard specifications. Coliforms were, however, isolated from some cocoa and tea products with moisture contents higher than 6% and 3% specified for these products. *Bacillus, Staphylococcus*, and moulds *Aspergillus, Penicillium* were isolated. Cocoa, coffee, and tea products specifically the refill packages should be properly stored after opening because some can be hygroscopic thus easily contaminated due to high moisture content.

9.2 Food Condiments

Food condiments (seasonings/spices) are substances added to food to enhance flavour or in some cultures complement the dish. Most locally made food condiments are fermented and their production often, by local technology creates room for contamination by diverse microorganisms, including mycotoxigenic moulds. Mycotoxins are hazardous to the health of both humans and animals (Corrier, 1991), they have been reported to be hepatotoxic, carcinogenic, mutagenic, immunosuppressive, nephrotoxic, dermatotoxic, neurotoxic, teratogenic, and immunotoxic (Ratcliff, 2002; CAST, 2003). Mycotoxins are also known to be stable under most food processing conditions and therefore persist in the final products.

Oranusi, Braide, Nwodo, and Nwosu (2013), assayed for aflatoxins in some local food condiments.

Table 4. Mean fungal count (cfu/g) of condiment samples

S. No.	SAMPLES	MEAN FUNGAL COUNT
1.	*Brachystegia eurycoma* (Achi)	8.2×10^9
2.	*Citrullus vulgaris* (mellon)	1.8×10^7
3.	*Monodora mystrica* (Ehuru)	< 10
4.	*Origanum syriacum* (Offor)	9.3×10^8
5.	*Piper guineense* (Uziza)	5.4×10^6
6.	*Pleurotus tuber regium* (Osu)	1.2×10^4
7.	*Ricinus communis* (ogiri)	8.8×10^6
8.	*Xylopia aethiopica* (Uda)	3.5×10^6

Table 5. Mycoflora and Aflatoxin assay of condiment samples

Table 5. Mycoflora and Aflatoxin assay of condiment samples

S. No.	SAMPLES	MICROORGANISMS	AFLATOXIN
1.	*Brachystegia eurycoma* (Achi)	*Aspergillus favus, Aspergillus niger, Penicillium spp*	++
2.	*Citrullus vulgaris* (mellon)	*Fusarium spp, Penicillium spp, Mucor spp, Aspergillus fumigatus*	–
3.	*Monodora mystrica* (Eburu)	*Rhizopus spp*	–
4.	*Origanum syriacum* (Offor)	*Penicillium spp, Aspergillus flavus, Rhizopus spp,*	+
5.	*Piper guineense* (Uziza)	*Aspergillus parasiticus, penicillium spp, Geotricum, Penicillium caseicolum, Aspergillus spp, Fusarium spp, Saccharomyces spp*	–
6.	*Pleurotus tuber regium* (Osu)	*Aspergillus spp, Candida spp, Mucor spp*	–
7.	*Ricinus communis* (ogiri)	*Penicillium spp, Aspergillus niger, Mucor spp, Aspergillus spp, Rhizopus spp*	–
8.	*Xylopia aethiopica* (Uda)	*Penicillium caseicolum, Rhizopus spp, Aspergillus spp, Penicillium spp*	–

We observed that the fungal counts were high, 10^4 - 10^9, and that there were diverse fungal contaminants (Tables 4 and 5). Two of the samples recorded aflatoxin contamination levels ≥ 20 ppb, which is higher than the acceptable limit. Food condiments/spices can be a veritable source of fungi/mycotoxin contamination to foods, effective HACCP should be employed in the processing of these products.

Food fortification is the deliberate increase of the content of essential micro-nutrients (vitamins and minerals, including trace elements) in a food so as to improve the nutritional quality of the food supply and provide a public health benefit with minimal risk to health (WHO/FAO, 2006; FFI, 2017). Salt is a major food condiment without which food is tasteless. It is the major source of iodine fortification to prevent iodine deficiency disorders (IDD) which affect the functions of vital organs and systems of the body, leading to damaging effects, particularly in pregnancy and early childhood, causing miscarriages, stillbirth, mental retardation, and increased infant mortality. Thus, salt can serve as a veritable source of both microbiological and nutrient safety concerns for man.
Oranusi, Chukwu, Onibokun, and Ajugwo (2017), did an assessment of microbiological qualities and iodine contents of some brands of domestic salt available in Nigeria (Tables 6 and 7).

Table 6. Mean (±SEM) total microbial count (cfu/g) after resuscitation

Parameter	SSA	SSB	SSC	ICMF, 1996 standard
TAPC	$1.1\times10^{1} \pm 0.00$	<10	$1.0\times10^{1} \pm 0.00$	$5 \times 10^{5} \pm 0.00$
TFC	<10	<10	<10	$1 \times 10^{2} \pm 0.00$
TSC	-	-	-	$1 \times 10^{4} \pm 0.00$
TCC	-	-	-	-

Key: TAPC = Total Aerobic Plate Count, TFC = Total Fungal Count, TSC = Total Staphylococci Count, TCC= Total Coliform Count, SSA = Salt sample company A, SSB = Salt sample company B, SSC = Salt sample company C, SEM = Standard Error of Mean

Table 7. Mean (±SEM) Iodine contents (ppm) of the samples

Fortificant	SSA	SSB	SSC	GAL
Iodine	$21.05 \pm 0.42^{*}$	$41.78 \pm 0.67^{*}$	29.70 ± 0.27	> 50 ppm iodine at port of entry and salt factory level > 30 ppm iodine at distributor and retail levels > 15 ppm iodine at household level (UNICEF, 2006).

Key: *Values differ significantly ($p< 0.05$) from the GAL
SSA = Salt sample (company A), SSB = Salt sample (company B), SSC = Salt sample (company C), GAL = Government approved level, SEM = Standard error of mean

Bacillus and fungal species were isolated after sample pre-enrichment and within counts (<10 to 10^{1} cfu/g) significantly ($p\leq 0.05$) lower than standard specifications. These isolates were, however, not confirmed to be either of autochthonous or allochthonous origin or halophiles. The iodine contents for the three brands were 21.05 ± 0.42, 41.78 ± 0.67, and 29.70 ± 0.27 (SSC). All the salt samples analysed except for SSC had iodine content significantly ($p\leq 0.05$) lower than the standard > 30 ppm iodine at distributor and retail levels and > 50 ppm iodine at the port of entry and salt factory level. This could indicate no compliance to standard specifications, an implication for nutrient unsafe food.

The Federal Government of Nigeria through its agency, the National Agency for Food and Drug Administration and Control

(NAFDAC) mandated vitamin A and mineral iron fortification of flour and flour products to improve the health and wellbeing of its citizens. According to UNESCO-Nigeria (2010), food fortification is the addition of food of nutrient component(s) that is not originally present in the food; it is a way of boosting the nutrient, to replace those that are lost during the preparation or processing of such foods. Many foods specifically staple foods are used as vehicles for fortification, these include but are not limited to whole wheat flour, maize flour, sugar, salt, vegetable oils, dairy products, and margarines (UNESCO Nigeria, 2010).

My research team (Chukwu, Braide, Anosike, and Oranusi, 2016), determined the Microbial Quality, Vitamin A, and Iron Contents in some Fortified Food Stuff Products Sold in Nigeria (Tables 8 and 9).

Table 8. Mean ±SD of total microbial count (cfu/g) of samples

TVMC	MRCF	AWF	BWF	DMF	CWF	r value Iron	r value Vit. A
TAPC	5×10^{5} ±0.00	8×10^{5}±2.97*	9×10^{5}±1.08*	3×10^{5}±1.08*	2×10^{5}±1.22*	-0.774	-0.684
TFC	1×10^{4}±0.00	3×10^{3}±1.77*	5×10^{4}±1.77*	2×10^{3}±1.08*	2×10^{4}±0.91*	-0.405	-0.798
TSC	1×10^{2} ±0.00	2×10^{2}±0.08	1×10^{2}±1.08*	1×10^{2}±0.00	-	-0.779	0.255

Key: *Values in the same row differ significantly ($p \leq 0.05$) from the MRCF.
SD= Standard deviation, cfu/g = Colony forming unit per gram, MRCF = Microbiological Reference Criteria for Foods requiring further cooking at >70°C, TVMC = Total Viable Microbial Count, TAPC = Total Aerobic Plate Count, TSC = Total Staphylococci Count, TFC = Total Fungi Count, AWF = Company A wheat flour, BWF = Company B wheat flour, DMF = Company D maize flour, CWF = Company C wheat flour, r value = Correlation value of TVMC to Iron or vitamin A concentration.

Table 9. Mean ± SD for levels of mineral Iron (Mg/Kg) and Vitamin A (IU/Kg) in the samples

Fortificants	GAL	AWF	BWF	DMF	CWF
Iron	40.70±0.00	52.56±0.69*	57.13±2.38*	58.28±0.29*	64.24±2.36*
Vitamin A	30000±0.00	27740±1.08*	24543±0.25*	6790±0.64*	13205±4.07*

Key: *Values in the same row differ significantly ($p \leq 0.05$) from the GAL.
SD = Standard deviation, GAL = Government approved level of fortificants, AWF = Company A wheat flour, BWF= Company B wheat flour, DMF= Company D maize flour, CWF= Company C wheat flour.

Samples of flour brands (wheat and maize flours) were tested for microbial load and levels of vitamin A and iron to ascertain the qualities and level of compliance with the fortification directives of the Federal Government of Nigeria. The total aerobic plate counts of the samples ranged from $2.0\times10^3 \pm 1.22$ cfu/g to $9.0\times10^3 \pm 1.08$ cfu/g. The fungal and *S. aureus* counts ranged from $2.0\times10^3 \pm 0.91$ cfu/g to $5.0\times10^4 \pm 1.77$ cfu/g and $1.0\text{x}10^2 \pm 0.00$ cfu/g to $1.0\text{x}10^3 \pm 1.08$ cfu/g. No coliform was isolated from the samples. Microbial species detected from the samples included *Bacillus, Staphylococcus, Aspergillus, Mucor,* and *Saccharomyces*. All the flour samples showed a significantly high ($p = 0.05$) level of iron above the recommended level of 40.70 Mg/Kg. However, the level of vitamin A in all the samples was significantly lower ($p = 0.05$) than the 30000±0.00 IU/Kg recommended for fortification. There was no positive correlation between iron and or vitamin A fortification and total viable microbial counts. There is an urgent need for consumer-level certification of products by regulatory agencies, to ensure that substandard goods are not produced and sold to consumers.

Cultures/tourism and the quest for foreign cuisines and for food containing plant products deemed to have antioxidant properties have culminated in the upsurge of importation for spices specifically from Asian countries. Oranusi, Nwachukwu, Adekeye, Dahunsi, and Oladipupo (2013), investigated the microbial profile, antibacterial and antioxidant activities of some imported spices in Nigeria (Tables 10 and 11).

Table 10. Mean microbial counts (cfu/g) of spice

Sample	TAPC	Coliform count	Fungi count
Ginger powder	$7.0\text{x}10^4$	$1.7\text{X}10^3$	$2.9\text{X}10^3$
Curry powder	$4.5\text{x}10^3$	$4.1\text{X}10^3$	$2.1\text{X}10^3$
Paprika powder	NG	NG	$1.0\text{X}10^1$
White pepper powder	$1.8\text{X}10^3$	$1.1\text{X}10^2$	$9.7\text{X}10^2$
Jeera powder	$3.8\text{X}10^3$	$3.9\text{X}10^3$	$1.9\text{X}10^3$

Table 11. Susceptibility test by agar well diffusion of spice extracts on the test isolates

Spice extract/ concentration(mg/ml)	Test organisms				
	S. aureus	*E. coli*	*K. pneumoniae*	*S. typhi*	*P. mirabilis*
Ginger powder					
25.0	S	R	R	S	R
12.5	R	R	R	R	R
6.25	R	R	R	R	R
Curry powder					
25.0	R	R	R	R	R
12.5	R	R	R	R	R
6.25	R	R	R	R	R
Paprika powder					
25.0	S	S	S	S	S
12.5	S	R	S	S	S
6.25	S	R	R	R	R
White pepper powder					
25.0	R	R	R	R	R
12.5	R	R	R	R	R
6.25	R	R	R	R	R
Jeera powder					
25.0	R	R	R	R	R
12.5	R	R	R	R	R
6.25	R	R	R	R	R

The mean (cfu/g) total aerobic plate counts in the samples ranged from 1.8×10^3 to 7.0×10^4, the Coliform count was 1.1×10^2 to 4.1×10^3, and the mean fungi count was 1.0×10^1 to 2.9×10^3. Microorganisms isolated from some of the spices include species of *Bacillus, Staphylococcus, Proteus, Enterobacter, Pseudomonas, Aspergillus, Rhizopus, and Fusarium*. Some of the spices had antimicrobial effects on the clinical isolates tested with MIC ranging from 6.25 to 25.0 mg/mL. The spices contained phenolics and flavonoids and had DPPH, Hydrogen peroxide, and Nitric oxide scavenging activities.

The health problems associated with the use of chemical preservatives cannot be over emphasized. The current trend is to search for natural food preservatives. The antifungal activities of lactic acid bacteria (LABs) from some spices were also evaluated, for activity against food spoilage moulds (Oranusi, Braide, and Oguoma, 2013).

Table 12. Susceptibility of fungal isolates to LAB

Fungal isolates	LAB isolates zones of inhibition (mm)								
	Posive control Fluconazol (4mg)	Pediococcus spp	Streptococcus spp	Lactobacillus spp	L. mesenteroides	L. lactis	L. plantarum	L. salivarius	Negative control Normal Saline
A. flavus	10	-	-	2	-	-	-	-	-
A. niger	16	-	-	-	-	15	-	3	-
A. fumigatus	20	-	13	15	10	8	-	-	-
Mucor spp	8	-	-	4	-	-	5	-	-
Penicillium spp	15	-	3	-	-	6	-	-	-
Rhizopus spp	6	-	-	-	-	4	-	-	-
A. nidulans	15	-	-	6	-	-	-	-	-

Table 12, present the antifungal activity of lactic acid bacteria (LAB) isolates from *Ricinus communis* (Ogiri), and *Pentaclethra macrophylla* (Ugba) against moulds associated with food spoilage *Aspergillus niger, Aspergillus flavus, Aspergillus fumigatus, Mucor, Penicillium, Rhizopus* and *Aspergillus nidulans*. The study indicated that the LAB isolates if optimized and improved could be used as a natural, food-grade bio-preservative agent for the management of fungal contamination and food spoilage, thus preventing problems associated with mycotoxins in food and feed products and with the health challenges associated with chemical preservatives.

9.3 Ready-to-Eat Foods/ Street Vended Foods

Food either raw or cooked, hot or chilled that is ready for immediate consumption at the point of sale without further treatment is generally described as "ready-to-eat food" (Tsang, 2002). The FAO defined street food as ready-to-eat foods and beverages prepared and/or sold by vendors and hawkers, especially in streets and other similar public places (FAO, 1989). The high level of unemployment and failed family and community values plus the change in social pattern characterized by increased mobility due to urbanization, a large number of itinerant workers, and fewer family or home-centered activities resulted in a large percentage of the population depending on ready-to-eat foods for employment and food. This situation, however, has resulted in the fact that food sanitary measures, and proper food handling has been transferred from individuals, families to the food vendors who rarely enforce such practices (Musa and Akande, 2002; Draper, 1996). My research team investigated several ready-to-eat foods, some of which include: Prevalence of multi-drug resistant bacteria associated with foods and drinks in Nigeria (2015-2020): A systematic review (Mola, Onibokun, Oranusi, 2021). Table 13 and Figures 9 and 10, present our findings.

Table 13. Frequency of MDR bacteria in foods and drinks

MDR bacteria	Frequency	Total no. of isolates	Number of MDR bacteria	% MDR Bacteria
Escherichia sp.	10	860	272	31.6
Staphylococcus sp.	9	286	131	45.8
Salmonella sp.	7	158	135	85.4
Bacillus sp.	5	90	14	15.6
Pseudomonas sp.	4	441	41	9.3
Shigella sp.	3	18	6	33.3
Proteus sp.	3	91	6	6.6
Klebsiella sp.	2	26	NA	–
Enterobacter sp.	2	51	28	35.3
Clostridium sp.	1	NA	NA	–
Alcaligens sp.	1	NA	NA	–
Lactobacillus sp.	1	NA	NA	–
Micrococcus sp.	1	66	66	100
Serratia sp.	1	12	NA	–
Vibrio sp.	1	NA	NA	–
Photobacterium sp.	1	NA	NA	–
Campylobacter sp.	1	NA	NA	–
Yersenia sp.	1	NA	NA	–
Propionibacterium sp.	1	NA	NA	–
Aeromonas sp.	1	NA	NA	–
Eubacterium sp.	1	NA	NA	–
Chromobacterium sp.	1	NA	NA	–
Treponema sp.	1	NA	NA	–
Enterococcus sp.	1	288	139	48
Total	61	2358	818	34.5

NA, Numbers of specific genera of the MDR bacteria were not specified in the studied articles.

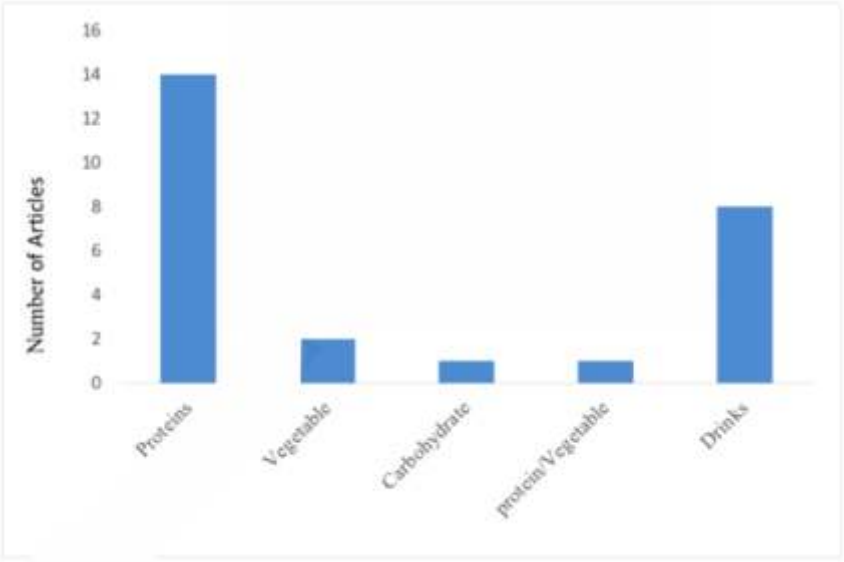

Figure 9: Frequency of occurrence of MDR bacteria among different food groups in articles included in data synthesis. NB: The result for drinks presented includes water.

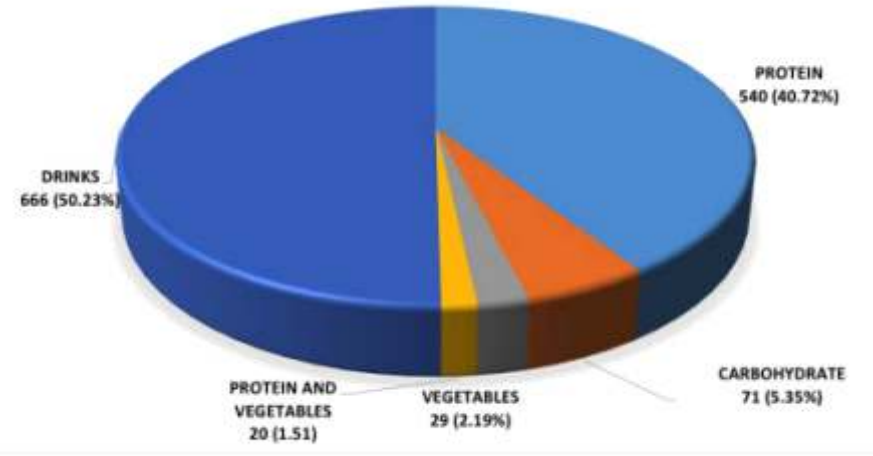

Figure 10: Number of MDR bacteria isolated from each food group. NB: The result for drinks presented includes water.

Foods are essential vehicles in human exposure to antibiotic-resistant bacteria, which serve as reservoirs for resistance genes and are a rising food safety concern. Antimicrobial resistance, including multidrug resistance (MDR), is an increasing problem globally and poses a serious concern to human health. This study was designed to synthesise data regarding the prevalence of MDR bacteria associated with foods and drinks sold within Nigeria. A comprehensive literature search on the prevalence of multi-drug resistant bacteria associated with foods and drinks in Nigeria from 2015 to 2020 was conducted using three databases: PubMed, Science Direct and Scopus. Of the total of one thousand three hundred and twenty-six MDR bacteria reportedly isolated in all twenty-six articles, the highest prevalence (660) was observed in drinks, including water, while the lowest (20) was observed in the article which combined results for both protein and vegetable-based foods. *Escherichia sp.* had the most frequency of occurrence, appearing as MDR bacteria in ten out of the twenty-six articles. Public health personnel need to ensure critical control during the production and handling of foods and drinks, as well as create more awareness of proper hygienic practices to combat the spread of MDR bacteria.

Diet is the most influential determinant of linear growth because it is through the diet that the influences of other determinants of linear growth such as infection and socioeconomic status (SES) are largely reflected. In Africa, the situation is acute considering the ravaging effects of inadequate food supply and poverty (Jyoti *et al.,* 2005; Ingbian and Akpapunam, 2005). This is of relevance in the education sector since improving childhood nutrition may have long-lasting educational benefits such as increased rates of secondary school completion in developing countries (Mendez, 2000). Provision of adequate energy intake and prevention of infection can be achieved through sustainable preventive strategies such as improving food production and water supply as well as promoting food and personal hygiene (Oranusi *et al*., 2006). Nutritional anthropometry has an important advantage over other nutritional indicators because it is sensitive to a full spectrum of malnutrition. In addition and more importantly, anthropometric measurements are inexpensive, practical, easy to use in large population-based field studies, non-invasive and age and sex-specific reference data are available (Saksvig *et al.,* 2005). Remember that my core interest as a food microbiologist is in the influence of food microbial load on consumers. Oranusi, Galadima, Umoh, and Nwanze (2007), did a food safety evaluation in boarding schools in Zaria, Nigeria, using the HACCP system. The report is as presented in Tables 14 and 15.

Table 14. Mean microbial counts (log_{10} $cfug^{-1}$) of breakfast meals prepared by five schools in Zaria, Nigeria

Organism	School	Milled Maize	Akamu	Temp (°C) [Time (min)]*	Milled Beans	Akara	Temp (°C) [Time (min)]*
TAPC	1	6.04± 2.7	4.23± 1.1[a]	60(30)	7.00 ± 3.1	5.40 ± 2.1	35(45)
	2	6.00 ± 2.7	4.94± 1.2[b]	60(30)	6.18 ± 2.1	5.70 ± 1.8	34(45)
	3	6.59 ± 3.7	4.20 ± 1.2[b]	38(90)	NA	5.40 ± 1.0	AMB(NT)
	4	5.94 ± 2.8	5.88 ± 3.1[a]	62(<30)	5.99 ± 1.5	4.08 ± 1.1	70(<30)
	5	5.90 ± 2.8	4.26 ± 1.9[b]	60(30)	6.04 ± 2.1	3.18 ± 0.1	36(45)
B. Cereus	1	5.91 ± 3.1	5.04 ± 2.2	60(30)	6.51 ± 2.7	4.06 ± 1.0	35(45)
	2	5.75 ± 2.6	4.67 ± 1.6	60(30)	5.95 ± 5.0	5.63 ± 1.8	34(45)
	3	6.62 ± 3.8	4.67 ± 1.7	38(90)	NA	6.20 ± 2.2	AMB(NT)
	4	6.11 ± 3.0	5.38 ± 2.5	62(<30)	5.92 ± 1.4	4.04 ± 0.6	70 (<30)
	5	5.88 ± 2.9	4.26 ± 1.9	60(30)	5.81 ± 2.2	3.72 ± 0.5	36(45)
S. aureus	1	4.79 ± 0.7	ND	60(30)	5.89 ± 1.6	4.00 ± 0.2	35(45)
	2	4.95 ±1.8	3.78 ± 1.2	60(30)	4.78 ± 0.9	ND	34(45)
	3	5.26 ± 2.2	3.18 ± 0.8	38(90)	NA	ND	AMB(NT)
	4	4.30 ± 0.0	ND	62(<30)	4.90 ± 1.5	ND	70 (<30)
	5	4.85 ± 0.0	ND	60(30)	5.15 ± 1.8	ND	36(45)
Coliform	1	4.48 ± 1.1	ND	60(30)	3.72 ± 1.0	2.18 ± 0.5	35(45)
	2	ND	ND	60(30)	3.56 ± 0.7	ND	34(45)
	3	4.88 ± 0.9	ND	38(90)	NA	1.80 ± 0.9	AMB(NT)
	4	ND	ND	62(<30)	2.61 ± 0.7	ND	70(<30)
	5	ND	ND	60(30)	2.48 ± 0.8	ND	36(45)

ND= Organism not detected; ± = Standard deviations; NT = Not tested; * = Temperature of internal portion (approximate center) of finished food and holding time before consumption ; NA = Not analyzed ; TAPC= Total aerobic plate count; AMB = Ambient temperature of 28° C. a, b, c = Means within column with the same letter for same count are not significantly different (p>0.05)

Table 15. Mean microbial counts (log_{10} $cfug^{-1}$) of raw and processed foods in five schools

Organism	School	Maize flour	Tuwo	Temp (°C) [Time(min)]*	Gari	Eba	Temp (°C) [Time(min)]*
TAPC	1	4.28 ± 2.0	4.23 ± 2.0^{b}	60(30)	2.58 ± 1.2^{b}	4.00 ± 1.0	60(30)
	2	4.84 ± 2.8	4.61 ± 2.5^{ab}	68(30)	4.49 ± 1.4^{a}	3.61 ± 1.6	71(<30)
	3	5.20 ± 3.4	5.04 ± 3.2^{a}	62(30)	4.72 ±1.9^{a}	ND	NT(30)
	4	4.15 ± 2.2	4.28 ± 2.2^{b}	50(36)	2.71 ± 0.6^{b}	ND	60(30)
	5	4.64 ± 2.3	4.45 ± 2.3^{ab}	50(35)	3.00 ± 0.6^{ab}	2.87 ± 1.3	70 (<30)
B.cereus	1	4.86 ± 3.0	4.90 ± 3.1^{ab}	60(30)	2.30 ± 1.6	4.41 ± 1.5^{a}	60 (30)
	2	4.59 ± 2.1	4.52 ± 2.2^{b}	68(30)	2.40 ± 0.4	2.26 ± 0.7^{b}	71(<30)
	3	4.46 ± 3.6	5.36 ± 3.6^{a}	62(30)	3.87 ± 1.1	1.70 ± 0.7^{b}	NT(30)
	4	3.95 ± 2.1	3.97 ± 2.0^{b}	50(35)	2.66 ± 1.1	3.59 ± 1.7^{a}	60(30)
	5	5.26 ± 3.4	4.62 ±2.4^{b}	50(30)	2.85 ± 1.3	3.15 ± 1.9^{a}	70(<30)
S. aureus	1	ND	ND	60(30)	ND	2.34 ± 0.2	60(30)
	2	ND	3.18 ± 0.0	68(30)	4.26 ± 1.0	4.11 ± 2.1	71(<30)
	3	4.54 ± 1.7	3.36 ± 0.5	62(30)	ND	ND	NT(30)
	4	3.49 ± 1.2	3.30 ± 0.0	50(35)	ND	ND	60(30)
	5	4.40 ± 0.0	3.40 ± 0.8	50(30)	ND	1.11 ± 0.3	70(<30)
Coliform	1	ND	2.70 ± 0.0	60(30)	ND	ND	60(30)
	2	ND	ND	68(30)	ND	ND	71(<30)
	3	3.04 ± 0.4	ND	62(30)	ND	ND	NT(30)
	4	ND	ND	50(35)	ND	ND	60(30)
	5	2.97 ± 0.2	ND	50(30)	ND	ND	70(<30)

ND = Organism not detected; NT = Not tested; a, b, ab = means within column with the same latter for same counts are not significantly different (P>0.05); ± = Standard deviation; * = Temperature of internal (approximate center) of finished food and holding time before consumption; TAPC = total aerobic plate count.

Evaluation of food safety was carried out in boarding schools in Zaria, Kaduna State. The analysis consisted of investigating hazards associated with microbial contamination and critical control points (CCPs) in the preparation and handling of foods in the schools. A concentration of 3 - 5log10 cells of *B. cereus*, 2 - 3log10 cells *of Staphylococcus aureus*, and 1- 2log10 coliforms were isolated per 100 g/mL of some of the cooked foods. The water was contaminated with coliforms below 2 log10 cells/mL. The food and water samples were found to have counts within acceptable limits but the isolation of enterotoxigenic strains of *B. cereus, S. aureus,* and *E. coli*, hazards such as inadequate (5 - 10 min) time/temperature exposure of foods (akamu, tuwo, eba), high-level initial contamination associated with raw foods, food ingredients, food contact surfaces, food handlers and inadequate cleaning of food utensils call for concern. The improvement of the personal hygiene of the handlers and the environment using hazard analysis critical control point (HACCP) could help in ensuring the safety of foods served in the boarding schools.

Still in line with the influence of safe food on the development and education of the child, my research team (Oranusi, Galadima, Umoh, and Nwanze, 2006) took a shot at the Energy intake and anthropometry: a case study of families in Zaria, Nigeria, Tables 16-19 present our findings.

Table 16. Means and standard anthropometric characteristics for different age groups

Age Group	Age (yrs)	Weight (Kg)	Height (m)	TSF (cm)	MAC (cm)	BMI (Kg/m^2)	EI (Kjd)
6-15							
Male	10.5 ± 1.2	28.5 ± 4.95	1.3 ±0.09	7.0 ± 0.02	18.0 ± 0.03	16.4± 0.78	4696 ± 480
Standard	-	29.4 (24.4 - 55.1)	1.53a (1.2 - 1.85)	8.1 (6.3 - 9.1)	21.4 (17.3 - 26.8)	20 - 25	9633.7
Female	11.5 ± 3.45	23.9 ± 8.72	1.2 ± 0.2	6.6 ± 0.92	17.6 ± 2.84	17.0 ± 5.63	4446 ± 4.3
Standard	-	27.3 (22.3 - 52.2)	1.5 (1.2 - 1.80)	10.3 (17.3 - 24.9)	21.2 (17.3 - 24.9)	20 - 25	8315.7
16 - 35							
Male	18.0 ± 1.63	55.5 ± 9.68	1.7 ± 0.05	9.3 ± 0.96	24.9 ±1.7	19.4±2.01	6493± 971
Standard	-	63.5 (58 - 73)	1.58 (1.45 - 1.92)	12.5	29.3	20-25	7196.5
Female	23.0 ± 5.53	58.8± 2.92	1.6 ± 0.08	10.7 ± 4.78	24.7 ± 4.1	21.9 ±3.61	5632± 2104
Standard	-	52.6 (48 - 61)	1.55 (1.4 - 1.69)	16.5	28.5	20 - 25	5714
36 - 55							
Male	44.3 ± 5.03	61.0 ± 6.0	1.7 ± 0.07	13.3 ± 6.26	27.8 ± 1.89	22.1 ± 1.82	7374 ± 545
Standard	-	63.5 (58 - 73)	1.55 (1.45 - 1.92)	12.5	29.3	20 - 25	6890.3
Female	41.3 ± 4.35	54.5 ± 8.3	1.6 ± 0.06	10.0 ± 4.08	26.0 ± 4.55	22.3 ± 3.08	4349 ± 517
Standard	-	52.6 (48 - 61)	1.55 (1.4 - 1.69)	16.5	28.5	20-25	5447.6
>55	58.0 ± 2.00	68.7 ± 11.93	1.6 ± 0.09	12.7 ± 3.06	28.2 ± 0.76	25.4 ± 4.62	10883 ± 3547
Standard	-	63.5 (58 - 73)	1.6 (1.45 - 1.92)	12.5 - 16.5	28.5 - 29.3	20 - 25	4870 - 5879

MAC = Mid Arm Circumference
BMI = Body Mass Index
EI = Energy Intake

Table 17. Mean Proximate composition per 100 g of foods prepared at homes

Food	Moisture (g)	Protein (g)	Carbohydrate (g)	Lipids (g)	Ash (g)	Na (mg)	K (mg)	Ca (mg)	Mg (mg)	Fe(mg)
Bean Cake/moimoi	72.97	7.81	13.80	3.12	2.28	986.6	530.5	197.3	114.6	1.49
Maize gruel (Akamu)	87.12	2.62	9.27	0.55	0.43	753.0	112.9	20.8	45.1	3.24
Tuwo (Corn meal)	73.33	3.63	21.39	0.79	0.86	619.0	259.9	14.2	43.3	1.05
Eba	76.40	0.50	21.73	0.88	0.49	123.7	216.8	2.7	63.9	1.57
Rice Jollof	70.68	3.46	22.66	1.90	1.12	958.7	262.9	8.5	194.0	1.04
Beans Jollof	67.82	8.19	15.64	5.17	1.23	812.3	976.7	181.1	124.9	1.73
Yam porridge	75.00	2.13	20.40	1.22	1.25	542.3	203.5	17.3	118.2	0.87
Beans/plantain porridge	62.53	6.55	25.79	3.12	1.40	673.6	1 015	283.8	196.9	1.91
Soyf G nut Soup	78.76	8.26	1.38	8.49	3.49	268.4	1073	326.4	139.1	1.71
Egg	73.40	11.80	-	12.3	1.21	136.0	136.0	56.0	12.3	2.53
Fried Fish	65.60	20.00	-	11.3	1.82	163.0	418.0	28.4	34.8	1.20
Orange	86.10	0.80	8.50	-	2.13	2.9	197.0	41.3	12.9	0.33
Egg plant	83.40	0.70	3.10	-	1.04	2.5	238.0	10.4	8.5	0.38
Sweet potatoes	72.00	1.10	20.10	-	1.83	17.8	296.0	20.5	12.3	0.62
Tomatoes	93.40	0.90	2.80	-	0.52	2.8	288.0	13.3	11.0	0.43
Bournvita	6.00	11.40	67.60	7.50	0.48	360.0	800.0	679.0	170.0	3.30
Doughnuts	28.40	6.00	48.80	15.80	2.10	80.0	113.0	67.0	16.4	1.92
Sugar	-	-	105.00	0.00	1.80	0.4	2.0	1.5	0.2	0.04
Biscuit	5.20	7.40	75.30	13.20	1.11	244.0	170.0	126.0	14.3	1.78
Spaghetti	12.40	9.90	84.00	1.80	0.74	4.8	161.0	22.8	34.9	1.21
Bread	53.80	7.80	92.70	1.40	2.21	515.0	191.0	92.0	22.6	1.80
Macaroni	72.20	3.40	25.20	0.80	0.62	7.9	67.0	8.1	17.6	0.45
Cornflakes	70.00	6.60	20.20	0.80	0.64	10.5	114.0	7.4	16.5	2.80
Custard	12.50	0.50	92.00	0.70	1.22	15.8	61.0	15.3	7.2	1.43
Butter	13.40	0.40	-	85.10	0.30	223.0	15.0	15.0	2.4	0.16
salt	-	0.00	0.00	0.00	0.02	38900	-	2.0	160.0	0.15

- Trace amount or not detectable

Table 18. Mean energy intake and anthropometry of subjects from small and large family sizes

Characteristics	Family Size	
	Small (below 10 persons)n=8	Large (above 10 persons) n = 14
Age (years)	24.6 ± 5.68	20.4 ± 5.13
Weight (Kg)	63.6 ± 16.29	54.40 ± 9.91
Height (m)	1.60 ± 0.08	1.60 ± 0.08
Triceps skin fold (mm)	11.80 ± 3.56	9.80 ± 4.29
Mid arm circumference (cm)	25.20 ± 3.31	24.20 ± 5.53
Body mass index (Kg/m^2)	24.20 ± 3.13	20.10 ± 3.87
Energy intake (Kj/d)	7746 ± 2644	540±983

Table 19. Mean energy intake and anthropometry of subjects from families of different socioeconomic status

Characteristics	Socio-economic status		
	Business trader(n = 10)	Civil servants (n =8)	Farmers (n = 4)
Age (years)	25.3 ± 2.52	25.74 ± 10.61	21.0 ± 6.17
Weight (Kg)	72.3 ± 14.64	53.8 ± 7.78	53.0±11.50
Height (m)	1.7 ± 0.07	1.6 ± 0.05	1.6 ± 0.11
Triceps skin fold (mm)	13.3 ± 3.79	10.0 ± 2.12	10.3 ± 5.77
Mid arm circumference (cm)	27.3 ± 1.94	23.0 ± 1.41	22.8 ± 7.25
Body mass index (Kg/m^2)	23.9 ± 5.07	19.9 ± 3.04	19.1 ± 4.99
Energy intake (Kj/d)	7539 ± 2636	5376 ± 783	5001 ± 889

The mean anthropometric values of participants reported were lower than those obtained from similar studies in Canada and the United Kingdom (Tanner and Whitehouse, 1962; Jenicek and Demirjian, 1972). This could be explained by underlying mild malnutrition in the subjects of study. There is thus an urgent need for research on diverse populations in developing countries over a long period in order to clarify ethnic differences in body composition and produce functional reference standards.

Oranusi, Galadima, and Umoh (2006) evaluated the Phage types and toxigenicity of *Staphylococcus aureus* strains from food contact surfaces and foods prepared in boarding schools in Zaria, Nigeria, We observed the result as presented on Tables 20 and 21.

Table 20. Distribution of strains of S. aureus by toxicity test, coagulase and haemolytic pattern

Test	No. positive n= 34	% of Total no tested
Coagulase:		
(a) Human plasma	15	44.1
(b) Sheep plasma	19	55.9
(c) Human and Sheep plasma	8	23.5
DNase	34	100
Haemolysis:		
(a) α- haemolytic	13	38.2
(b) β- haemolytic	16	47.1
(c) γ- haemolytic	5	14.7
Cat Emetic Response:		
(a) Milk feed	3	8.8
(b) Rice feed	1	2.9
(c) Milk and Rice feed	3	8.8
Total*	7	20.6

*= Total enterotoxigenic strains by emetic response n= number of isolates tested

Table 21. Distribution of toxigenic strains (n=7) of S. aureus by source of isolation

Source	No. of isolates tested (% total)	Cat emetic response (% n)	Coagulase			Haemolysis		DNase
			Hp	Sp	Hp + Sp	A	β	
(a) Ready to eat food	6(17.7)	-	-	-	-	-	-	-
(b) Raw food	22(64.7)	5(71.4)	3	2	2	4	1	5
(c) Food contact surfaces	3(8.8)	1(14.3)	-	1	-	1	-	1
(d) Food handlers	3(8.8)	1(14.3)	1	-	-	1	-	1
Total	34(100)	7(20.6)*	4(57.1)	3(42.9)	2(28.6)	6(85.7)	1(14.3)	7(100)

- = no reaction, * = % of total (n=34), Hp= Human plasma, Sp= sheep plasma

Out of 34 *S. aureus* strains isolated from food-contact surfaces and foods prepared in five schools with boarding facilities in Zaria, 7(20.6%) were toxigenic using cat toxicity test. Thirteen (38.2%) were alpha-haemolytic, 16(47.1%) beta-haemolytic, 19(55.9%) coagulated sheep plasma, 15(44.1%) coagulated human plasma while 8(23.5%) coagulated both human and sheep plasma. All the 34 strains were DNase positive. Thirty-two (94.1%) were typable at routine test dilution (RTD), 28(82.3%) showed strong lysis while 4(11.8%) showed weak lysis. Nineteen (59.4%) of the typable strains were by group IV phage set and 9(28.1%) by group III phages. The isolation of toxigenic strains of *S. aureus* and the

presence of alpha-haemolytic and phage group III strains of *S. aureus* in food is of concern because alpha-haemolytic strains are known to be toxigenic and phage group III strains have been implicated frequently in foodborne diseases. Hazard analysis critical control point (HACCP) of food is recommended to control and prevent presence of toxigenic strains of organisms in food served to students in the boarding schools.

My research team also investigated the microbiological quality of foods sold in students' cafeterias (Oranusi, Oguoma and Agusi, 2013). The report is presented in **Table 22 and Figures 11 and 12.**

Table 22. Mean microbial population of the food samples (cfu/g)

Food samples	SITE I University campus community			SITE II University host community		
Food samples	Total aerobic plate count	Fungal counts	Coliform count	Total aerobic plate count	Fungal counts	Coliform count
Jollof rice	2.5×10^3a	6.0×10^2a	3.2×10^3a	2.7×10^3a	9.0×10^3b	5.2×10^3a
Coleslaw	9.1×10^6b	7.3×10^4b	3.4×10^4a	9.8×10^6b	9.3×10^6c	8.5×10^3a
Fried rice	8.2×10^4a	8.0×10^3b	3.4×10^4a	6.0×10^5c	7.8×10^4a	4.2×10^4ab
Moi-moi	7.0×10^4a	9.0×10^3b	5.1×10^3a	5.0×10^3a	4.5×10^6b	7.8×10^4ab

abc= Values with same alphabets for same foods and counts across the rows and same counts down the column are not significantly different.

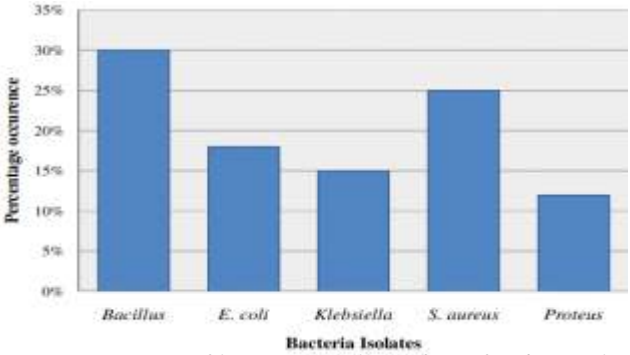

Figure 11: Percentage occurrence of bacteria isolates from food samples

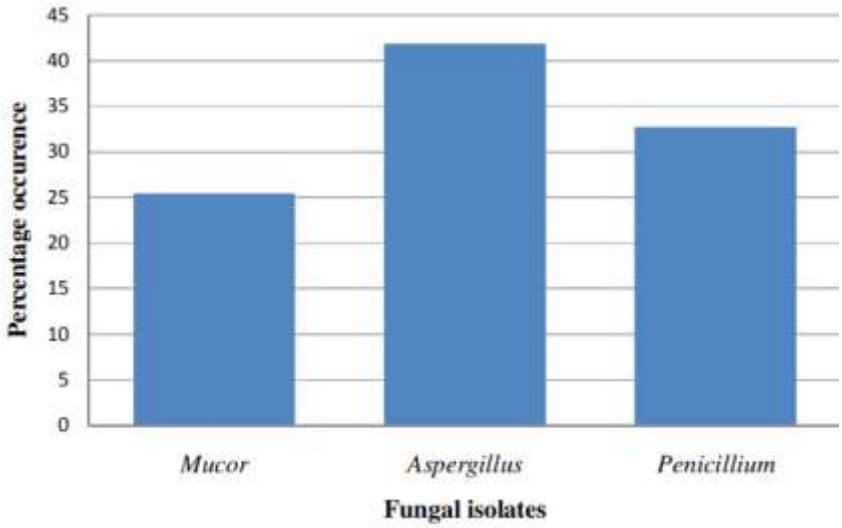

Figure 12: Percentage occurrence of fungi isolates from food samples

The microbiological quality of ready-to-eat food (RTEF) products sold on a University Campus was studied. A total of forty-eight food samples, including coleslaw, fried rice, jollof rice, and Moi-Moi were collected from two food vending sites which serve as the major ready to eat food vending centres to the student community. The mean total aerobic plate count, coliform count, and fungal count from SITE I ranged from 2.5×10^3 to 9.1×10^6, 3.2×10^3 to 3.4×10^4, and 6.0×10^2 to 7.3×10^4 respectively. SITE II had aerobic plate count, coliform count, and fungal plate count ranging from 2.7×10^3 to 9.8×10^6, 5.2×10^3 to 7.8×10^4, and 9.0×10^3 to 9.3×10^6 respectively. Based on the specifications by International Commission for Microbiological Specification for Foods (ICMSF), the level of contaminations was within acceptable microbiological limits (satisfactory) except for coleslaw; this could be attributed to extensive handling, mixing, and the fact that it is consumed as raw food. It is recommended that closer and stringent supervision of ready-to-eat foods sold to students in the University should be carried out by relevant authorities to prevent possible outbreaks of foodborne illnesses.

My research team also investigated the microbial quality of foods prepared in families and we reported (Tables 23-25) based on the HACCP of Foods Prepared by the families (Oranusi, Onyike, Galadima and Umoh, 2004).

Table 23. Mean microbial counts (log_{10} $cfug^{-1}$) of raw and processed foods in five families

Organism	Family	Maize flour	Tuwo	Temp. °C* [Time (min)]*	Gari	Eba	Temp. °C* [Time (min)]*
TAPC	1	4.61±4.6	4.66±4.6^{a}	65(30)	1.00±0.2	ND	NT(30)
	2	4.15±4.2	4.20±3.8^{b}	50(30)	1.88±1.5	4.56±3.7	40(30)
	3	4.97±4.7	4.52±4.3^{ab}	58(35)	2.00±1.4	1.69±1.2	50(30)
	4	4.36±4.4	4.00±4.0^{a}	50(30)	2.68±1.2	ND	45(35)
	5	5.46±5.7	3.39±3.9^{b}	50(30)	**	**	**
B. cereus	1	4.57±4.6	4.85±5.0	65(30)	2.40±1.4	ND	NT(30)
	2	4.00±3.8	ND	50(30)	ND	4.56±2.6^{a}	40(30)
	3	4.66±4.6	4.38±4.2	58(35)	2.98±0.8	4.00±1.6^{a}	50(30)
	4	4.20±4.1	4.11±4.2	50(30)	3.65±2.2	2.40±1.9^{b}	45(35)
	5	4.98±4.8	4.83±4.7	50(30)	**	**	**
S. aureus	1	3.00±0.0	ND	65(30)	ND	ND	NT(30)
	2	ND	ND	50(30)	ND	ND	40(30)
	3	3.74±3.8	3.40±0.0	58(35)	ND	ND	50(30)
	4	3.18±0.0	ND	50(30)	1.23±0.8	ND	45(35)
	5	ND	ND	50(30)	**	**	**
Coliform	1	2.88±2.3	ND	65(30)	ND	ND	NT(30)
	2	ND	ND	50(30)	ND	ND	40(30)
	3	ND	ND	58(35)	ND	ND	50(30)
	4	ND	ND	50(30)	ND	ND	45(35)
	5	5.28±4.8	4.04±2.7	50(30)	**	**	**

**= Food not prepared in family, ND= Organism not detected, NT= Not tested, a,b,c= Mean within column with the same letter for same count are not significantly different (p=0.005), ±= Standard deviation, *= Temperature of the internal portion (approximate centre) of the finished food and holding time before consumption, TAPC= Total aerobic plate count

Table 24. Mean microbial counts (log_{10} $cfug^{-1}$) of breakfast meals prepared by five families in Zaria, Nigeria

Organism	Family	Milled maize	Akamu	Temp. °C* [Time (min)]*	Milled Beans	Akara	Temp. °C* [Time (min)]*
TAPC	1	5.65±5.3	4.32±4.1	40(45)	7.00±6.4	3.00±2.4	NT
	2	5.11±4.1	4.30±0.0	50(40)	ND	2.39±1.8	NT
	3	5.96±5.8	4.60±4.5	49(40)	ND	3.11±2.5	NT
	4	4.97±4.7	4.30±0.0	60(30)	4.74±4.7	2.65±	31(40)
	5	5.81±5.9	4.20±4.0	62(30)	**	**	**
B. cereus	1	5.43±5.2^{bc}	4.64±4.7	40(45)	6.81±5.8	ND	NT
	2	4.18±3.2^{c}	4.18±4.1	50(40)	ND	ND	NT
	3	5.72±3.8^{abc}	4.59±4.3	49(40)	ND	2.39±2.4	NT
	4	6.11±6.0^{a}	4.08±3.4	60(30)	4.58±4.4	2.23±2.1	31(40)
	5	6.18±5.7^{a}	4.95±4.8	62(30)	**	**	**
S. aureus	1	5.08±5.0	ND	40(45)	6.30±	ND	NT
	2	3.69±2.3	ND	50(40)	ND	ND	NT
	3	5.11±5.0	ND	40(40)	ND	2.58±2.6	NT
	4	ND	ND	60(30)	ND	2.00±0.8	31(40)
	5	5.32±5.3	ND	62(30)	**	**	**
Coliform	1	3.72±2.6	2.00±1.8	40(45)	ND	ND	NT
	2	ND	ND	50(40)	ND	ND	NT
	3	ND	ND	49(40)	ND	ND	NT
	4	ND	ND	60(30)	ND	ND	31(40)
	5	4. 82±3.8	ND	62(30)	**	**	**

**= Food not prepared in family, ND= Organism not detected, NT= Not tested, a,b,c= Mean within column with the same letter for same count are not significantly different (p>0.005), ±= Standard deviation, *= Temperature of the internal portion (approximate centre) of the finished food and holding time before consumption, TAPC= Total aerobic plate count

Table 25. Mean microbial counts (log_{10} $cfug^{-1}$) of vegetable, soup and spices from five families in Zaria

Organism	Family	Vegetable	Spices	Soup	Temp. °C* [Time (min)]*
TAPC	1	7.00±0.0[a]	6.20±0.0	3.74±0.0a	70(?30)
	2	7.15±6.7[a]	6.00±5.9	6.70±6.9b	50(30)
	3	5.92±6.1[b]	6.20±4.8	3.36±3.5a	55(30)
	4	7.15±6.4[a]	5.98±5.8	2.76±2.7a	NT
	5	6.70±5.6[ab]	6.20±4.9	3.34±3.4a	56(30)
B. cereus	1	6.81±0.0[ab]	5.63±5.4	3.46±3.5a	70(30)
	2	6.79±6.1[ab]	6.49±6.6	6.11±6.2b	50(?30)
	3	5.81±6.0[b]	5.72±4.4	3.68±3.8a	55(30)
	4	7.00±6.1[b]	5.23±5.3	2.80±2.8a	NT
	5	6.32±6.3[bc]	5.59±5.4	3.23±3.3a	56(30)
S. aureus	1	6.30±0.0	5.18±4.8[b]	ND	70(30)
	2	6.18±6.0	4.45±4.0[c]	5.48±4.0	50(30)
	3	4.63±4.8	5.88±0.0[a]	ND	55(30)
	4	6.36±5.5	5.11±4.8[bc]	ND	NT
	5	6.85±6.5	4.92±4.1[bc]	ND	56(30)
Coliform	1	ND	ND	ND	70(?30)
	2	6.36±0.0[a]	ND	ND	50(30)
	3	2.93±0.0[b]	ND	ND	55(30)
	4	6.20±6.2[a]	5.40±4.6	ND	NT
	5	6.08±5.2[a]	ND	ND	56(30)

ND= Organism not detected, NT= Not tested, a,b,c= Mean within column with the same letter for same count are not significantly different ($p>0.005$), ±= Standard deviation, *= Temperature of the internal portion (approximate centre) of the finished food and holding time before consumption, TAPC= Total aerobic plate count

However, 2-4 log_{10} cells of *B. cereus*, 2-3 log_{10} cells of *S. aureus* and $2log_{10}$ cells of coliforms were isolated per gram/mL some of the cooked foods. The water samples for drinking, cooking and washing dishes were contaminated with coliforms below $2log_{10}$ cells/mL. Out of 28 *B. cereus* and 14 *E. coli* strains tested for enterotoxin production, 16(57.1%) *B. cereus* and 3(21.4%) *E.coli* were toxigenic. Though the level of counts were within acceptable limit for food and water, the presence of enterotoxigenic strains of *B. cereus* and *E. coli* and the hazards such as inadequate cleaning of food utensils, high level initial contamination associated with the raw foods, food ingredients, food contact surfaces and the food handlers call for concern. HACCP is advanced to ensure good personal hygiene and environmental sanitation in order to obtain safe prepared foods.

Snacks are ready-to-eat food; the preparation involves extensive mixing and handling of ingredients. Some ready-to-eat foods are

regarded as potentially hazardous, because such foods can support the growth of pathogens (Oranusi, Omagbemi, and Eni, 2011). Pastas, include, but are not limited to sandwiches, kebabs, hotdogs, meat pie, salad, doughnuts, takeaway foods and bakery products. Ready-to-eat foods usually include a number of ingredients, which may or may not be cooked. Due to the nature of these foods and their methods of preparation involving extensive handling, they are usually prone to contamination/cross contamination from soil, water, air, storage/distribution facilities, environment and human activities (food handlers and vendors). My research team looked at the microbiological safety of snacks sold in fast food shops in Ota, Ogun State, Nigeria. The report is as presented on Figures 13 and 14, and Tables 26-28.

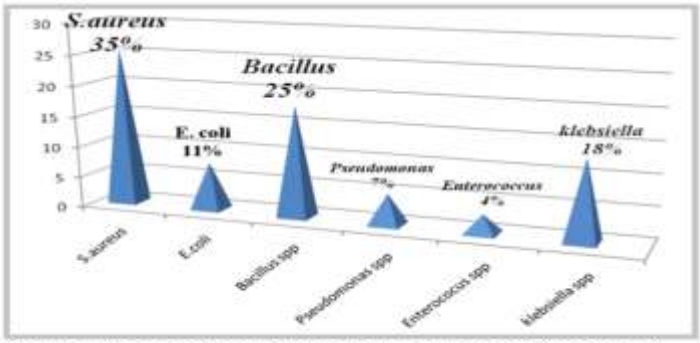

Figure 13: Percentage occurrence of bacterial isolates from samples

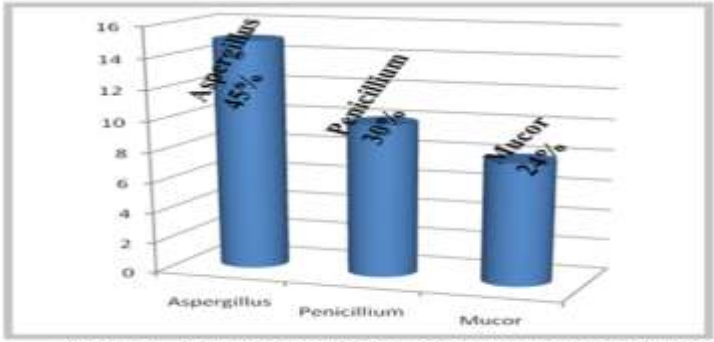

Figure 14: Percentage occurrence of fungal isolates from samples

Table 26. Mean total aerobic plate count (cfu/g) of snacks

Food sample	Source of samples		
	University cafeteria	Snacks bar	Local kiosk
MEAT PIE	$2.0 \times 10^{3}_{a}$	$2.7 \times 10^{4}_{a}$	$2.1 \times 10^{3}_{a}$
HOTDOG	$2.0 \times 10^{3}_{a}$	$2.8 \times 10^{3}_{a}$	$5.4 \times 10^{5}_{b}$
SAUSAGE	$3.0 \times 10^{4}_{a}$	$3.3 \times 10^{4}_{a}$	$8.0 \times 10^{3}_{a}$
EGG ROLL	$8.2 \times 10^{3}_{a}$	$5.8 \times 10^{5}_{b}$	$4.8 \times 10^{4}_{ab}$
DOUGHNUT	$1.1 \times 10^{3}_{a}$	$2.0 \times 10^{3}_{a}$	$3.0 \times 10^{4}_{a}$

a, b= Mean within row with the same letter for same count are not significantly different ($p>0.05$)

Table 27. Mean fungal count (cfu/g) of snacks

Food sample	Source of samples		
	University cafeteria	Snacks bar	Local kiosk
MEAT PIE	NG	3.0×10^{2}	NG
HOTDOG	NG	2.0×10^{2}	2.0×10^{2}
SAUSAGE	4.0×10^{2}	NG	3.0×10^{2}
EGG ROLL	3.4×10^{2}	2.8×10^{2}	4.0×10^{2}
DOUGHNUT	2.0×10^{2}	1.0×10^{2}	NG

Table 28. Mean coliform count (cfu/g) of snacks

Food sample	Source of samples		
	University cafeteria	Snacks bar	Local kiosk
MEAT PIE	NG	$6.0 \times 10^{2}_{a}$	$2.0 \times 10^{2}_{a}$
HOTDOG	$1.0 \times 10^{2}_{a}$	$1.4 \times 10^{2}_{a}$	$5.0 \times 10^{2}_{a}$
SAUSAGE	$2.2 \times 10^{3}_{a}$	$1.8 \times 10^{5}_{b}$	$1.0 \times 10^{3}_{a}$
EGG ROLL	$6.0 \times 10^{2}_{a}$	$1.0 \times 10^{3}_{a}$	$8.0 \times 10^{4}_{a}$
DOUGHNUT	NG	NG	$1.0 \times 10^{2}_{a}$

a, b= Mean within row with the same letter for same count are not significantly different ($p>0.05$)

The microbial quality of snacks (ready-to-eat foods), sold in Ota, Ogun State was investigated. A total of 100 different samples from 3 vending sites namely, a University Cafeteria, a top-class snacks bar,

and a local kiosk were analysed for total aerobic plate count, coliform count, and specific pathogens and fungi. Six different bacterial and three fungal isolates were identified to include *E. coli*, *S. aureus*, *Bacillus cereus*, *Enterococcus*, *Klebsiella spp, Pseudomonas spp, Aspergillus niger*, *Penicillium spp,* and *Mucor*. The presence of *E. coli* and Enterococci which are indicator organisms call for concern. Adoption of good manufacturing practices and HACCP are necessary to prevent the occurrence of food-borne illness (Oranusi, Omagbemi, and Eni, 2011).

Oranusi and Braide (2012a); Oranusi and Nubi (2016), did some studies on the microbial safety of **ready-to-eat foods vended on highways** (Tables 29-31), this is because the danger associated with ready-to-eat foods is further heightened with migratory ready-to-eat food vendors. While the stationary and ambulatory vendors can exercise some food safety caution, in order to produce safe product for their clients, and for fear that a bad product can lead to low patronage by consumers, or outright confrontation by customers because the vendor is known by their fixed station/location/routes, the migratory vendors have no fixed station/location/route/identity. Thus, can sell anything to the consumers (travellers).

Table 29. Mean total aerobic bacterial count of ready-to-eat foods sold on the highways

Sample	Sampling Location					
	Oba	Okija	Ihiala	Mgbidi	Awomama	Ogbaku
Okpa	$2.1x10^7$	$1.3x10^9$	$4.5x10^5$	$3.4x10^6$	$5.2x10^6$	$6.4x10^5$
Apple	$4.3x10^6$	$2.5x10^9$	$3.1x10^7$	$1.2x10^5$	$2.2x10^5$	$4.4x10^6$
Wall nut	$7.1x10^9$	$6.3x10^9$	$1.8x10^8$	$3.7x10^9$	$3.5x10^6$	$8.5x10^7$
Meat pie	$2.9x10^5$	$5.6x10^6$	$8.1x10^5$	$2.3x10^6$	$2.5x10^4$	$4.5x10^6$
Pealed Orange	$2.4x10^5$	$5.3x10^5$	$1.8x10^6$	$2.4x10^5$	$6.5x10^4$	$2.2x10^4$
Plantain chips	$8.2x10^6$	$3.4x10^6$	$2.2x10^5$	$1.5x10^5$	$2.7x10^7$	$5.5x10^3$
Aki-na-Ukwa	$3.3x10^4$	$4.2x10^6$	$5.6x10^6$	$4.6x10^5$	$4.3x10^6$	$3.1x10^5$
Egg roll	$6.5x10^6$	$7.1x10^3$	$6.3x10^5$	$5.1x10^5$	$1.1x10^4$	$7.3x10^3$
Doughnut	$1.7x10^3$	$3.1x10^4$	$5.4x10^5$	$4.3x10^5$	$2.5x10^6$	$3.3x10^4$
Elulu-ngwo	$2.6x10^7$	$2.4x10^7$	$1.3x10^6$	$4.2x10^7$	NA	NA
Sliced Pineapple	$1.0x10^7$	$4.6x10^6$	$6.6x10^9$	$9.3x10^6$	$6.0x10^6$	$3.6x10^7$
Cashew nut	$5.9x10^3$	$8.7x10^5$	$7.7x10^4$	$6.8x10^5$	$7.4x10^6$	$1.7x10^4$
Ground nut	$9.8x10^4$	$1.2x10^4$	$2.7x10^5$	$1.1x10^4$	$6.7x10^4$	$5.8x10^5$
Beef sausage roll	$3.4x10^4$	$6.8x10^4$	$4.6x10^4$	$3.8x10^5$	$4.8x10^5$	$6.6x10^4$

NA– Not analyzed

Table 30. Mean coliform count of ready-to-eat foods sold on the highways

Sample	Sampling Location					
	Oba	Okija	Ihiala	Mgbidi	Awomama	Ogbaku
Okpa	$2.1x10^5$	$1.8x10^6$	$5.5x10^6$	$6.3x10^5$	$3.2x10^4$	$2.7x10^4$
Apple	$3.1x10^5$	$3.0x10^6$	$3.3x10^6$	$1.2x10^5$	$1.1x10^2$	$5.4x10^2$
Wall nut	$6.4x10^6$	$7.1x10^5$	$4.9x10^6$	$3.8x10^7$	$4.1x10^5$	$7.2x10^6$
Meat pie	$1.4x10^2$	$2.3x10^2$	$3.1x10^3$	$3.3x10^2$	$1.3x10^2$	$2.5x10^4$
Poalod Orange	$2.3x10^1$	$3.3x10^2$	$1.7x10^3$	$2.8x10^1$	$2.1x10^2$	$2.4x10^2$
Plantain chips	$4.1x10^3$	$1.2x10^3$	$1.1x10^3$	$3.0x10^3$	$1.3x10^3$	$2.7x10^3$
Aki-na-Ukwa	$2.3x10^2$	$2.2x10^3$	$7.1x10^4$	$1.5x10^2$	$3.3x10^3$	$1.1x10^3$
Egg roll	$6.5x10^6$	$7.1x10^3$	$6.3x10^5$	$5.1x10^5$	$1.1x10^4$	$7.3x10^3$
Doughnut	$3.2x10^1$	$1.1x10^4$	$4.4x10^5$	$8.3x10^4$	$2.7x10^4$	$2.1x10^4$
Elulu-ngwo	$2.5x10^4$	$4.2x10^3$	$2.5x10^5$	$3.1x10^4$	NA	NA
Sliced Pineapple	$2.0x10^6$	$8.2x10^6$	$2.2x10^7$	$8.3x10^5$	$3.3x10^7$	$3.4x10^6$
Cashew nut	$1.8x10^3$	$6.4x10^2$	$4.8x10^2$	$3.4x10^3$	$3.7x10^3$	$5.3x10^4$
Ground nut	$4.3x10^4$	$1.1x10^4$	$3.3x10^2$	$3.5x10^2$	$4.4x10^3$	$4.6x10^3$
Beef sausage roll	$3.3x10^2$	$3.2x10^2$	$4.3x10^3$	$1.9x10^3$	$2.4x10^2$	$3.6x10^3$

NA– Not analyzed

Table 31. Mean microbial counts of RTE shrimps and snails (cfu/g) sample

Sample Site	Capitulum of shrimps		Abdomen of shrimps		Snails	
	Staphylococcal count	*Salmonellae* count	Staphylococcal count	*Salmonellae* count	Staphylococcal count	*Salmonellae* count
Berger	$2.9 x10^{3a}$	$1 x 10^{1a}$	$4.0 x10^{1b}$	NG	$3.8 x10^{2c}$	NG
Mowe	$1.8 x10^{2d}$	$1 x 10^{1a}$	$1.6 x10^{2e}$	NG	$1.7 x10^{2e}$	NG
Ibafo	$5.7 x10^{2f}$	$1.1 x10^{2b}$	$2.9 x10^{2g}$	$1.1 x10^{1a}$	$3.6 x10^{2h}$	$1.0 x 10^{1a}$

abcdefgh: Values with same alphabet superscript down the column and across the row for same count are not significantly different

These studies revealed that while some of the foods vended by these migratory food vendors are contaminated beyond acceptable microbiological limits, most of the foods are of satisfactory microbiological standard. Foods vended along the highways supply the energy and nutrient need of the travellers and create employment to the teaming unemployed youths (vendors) however, the danger associated with migratory food vendors of unknown identity, untrained in food safety and of unknown educational background is enormous and must be discouraged.

Canned foods have been reported to be contaminated mainly by spore forming bacteria of the genera *Bacillus, Clostridium* and *Desulfotomaculum* (Stersky, Todd and Pivnick, 1980; Put, Van-Doren, Warner and Kruiswijk, 1992). If the contaminant is a pathogen and the food is capable of supporting its growth, a health hazard exists. My research team Oranusi, Braide and Osigwe (2012), investigated the microbial profile of some canned foods. Table 32 presents the mean pH and total plate counts of canned foods after pre-enrichment.

Table 32. Mean pH and total plate counts of canned foods

Canned Foods	Mean Total Plate Count cfu/g							
	Aerobic incubation			Anaerobic incubation			Coliform Count	Mean pH
	15°C	37°C	55°C	15°C	37°C	55°C		
Meat	-	$5.0x10^1$	< 10	-	$1.0x10^1$	<10	-	6.24
Milk	-	$1.0x10^2$	-	<10	-	<10	-	6.20
Mixed Vegetables	-	$1.4x10^3$	$1.0x10^1$	<10	$1.0x10^2$	<10	$2.0x10^2$	5.30
Sardine	-	$2.1x10^1$	$1.1x10^1$	-	$1.2x10^1$	<10	<10	6.12
Tomatoes	-	$1.3x10^2$	<10	-	<10	<10	-	4.25

- = No growth at expiry of incubation time

Canned food samples comprising Sardines, Milk, Tomatoes, Meat, and mixed vegetables were randomly collected from superstores, kiosks, and local markets. All samples were within the expiry date, none of which was bloated, leaking, and/or physically damaged. Some of the samples yielded microbial growth and more growth from pre-enriched samples. That the pre-enriched samples yielded more organisms than the direct culture could be explained by the fact that shelf-stable canned foods packed in hermetically sealed containers are not absolutely sterile and thus contain injured and suppressed micro-organisms that could proliferate if storage conditions and integrity of the container are compromised. Regular surveillance and checks to monitor canned foods on sales are, therefore, necessary for effective food safety.

Grilled, roasted, and smoked foods go through extensive handling by both the food vendors and the customers, thus can be a veritable source of foodborne infection. Oranusi, Onibokun,

Obafemi, and Dureke (2018), worked on the microbiology, heterocyclic amines, and polycyclic aromatic hydrocarbons profiles of some grilled, roasted, and smoked foods in Lagos and Ogun States, Nigeria.
Results are as presented on Table 33, and Figures 15a,b.

Table 33. Mean microbial count (cfu/g) sample marketed in Lagos and Ogun States, Nigeria

Sample	Total aerobic plate count		Fungal count		Coliform count	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Grilled fish	$8.39\times10^{6}\pm6.57\times10^{5}$	$2.7\times10^{5}-2.1\times10^{6}$	$1.17\times10^{5}\pm8.26\times10^{3}$	$0-7.1\times10^{5}$	-	NG
Smoked fish	$9.15\times10^{7}\pm2.43\times10^{5}$	$4.9\times10^{5}-4.0\times10^{8}$	$8.36\times10^{6}\pm1.04\times10^{7}$	$0-2.3\times10^{8}$	$5.42\times10^{6}\pm4.00\times10^{5}$	$0-4.8\times10^{7}$
Grilled meat	$5.06\times10^{6}\pm5.66\times10^{5}$	$1.8\times10^{5}-1.3\times10^{7}$	$1.86\times10^{6}\pm1.84\times10^{7}$	$0-3.7\times10^{8}$	$5.40\times10^{6}\pm3.06\times10^{5}$	$0-6.0\times10^{7}$
Smoked meat	$2.00\times10^{7}\pm1.41\times10^{5}$	$2.2\times10^{5}-2.0\times10^{7}$	$3.82\times10^{6}\pm2.00\times10^{7}$	$0-4.7\times10^{8}$	NG	NG
Roasted plantain	$1.62\times10^{6}\pm1.73\times10^{5}$	$1.7\times10^{5}-4.2\times10^{6}$	$2.18\times10^{6}\pm9.38\times10^{5}$	$0-3.5\times10^{6}$	NG	NG
Roasted Yam	$6.05\times10^{5}\pm7.47\times10^{4}$	$2.3\times10^{5}-7.7\times10^{5}$	NG	NG	NG	NG

KEY: NG= No growth less than 10.

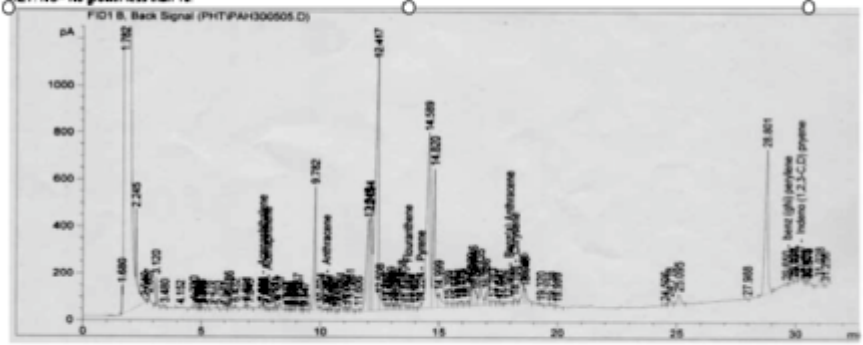

Figure 15a: PAH detected in grilled fish marketed in Lagos and Ogun States, Nigeria.

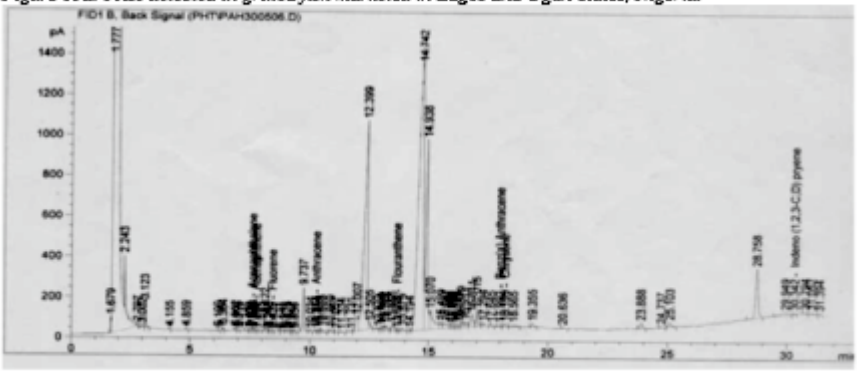

Figure 15b: PAH detected in grilled meat marketed in Lagos and Ogun States, Nigeria.

We reported that the dietary intake of polycyclic aromatic hydrocarbons (PAHs) and heterocyclic amines (HCA) has posed a great health risk as they have been identified as the most potent human carcinogen. The microbial quality of food is also of concern as they contribute to food poisoning and infection. Sixty food samples comprising roasted yam, plantain, grilled, and smoked fish and meat were randomly sampled from Lagos and Ogun States, Nigeria, and the PAHs, HCAs contents, and the microbial load were determined. PAHs were detected in some grilled, roasted, and smoked samples and with the highest concentrations of 314.85 and 139.97 μg/g of Dibenzene[a,h]anthracene established in roasted yam and smoked fish samples. Only 2-amino-1-methyl-6-phenylimidazo[4,5-b]pyridine (PhIP) was detected in grilled fish and meat samples. This study, therefore, established the presence of chemical and microbial contaminants in some of the food items investigated. It recommended that strict sanitary practices and appropriate cooking methods be enforced during food preparation.

9.4 Fruits and Fruit Juices

Fruits are a vital part of the human diet as they provide antioxidants, low-calorie and protective micronutrient-rich diets (Sachdeva *et al.,* 2013). They have been associated with reduced blood cholesterol, prevention of large bowel diseases, reduced incidence of cancer and cardiovascular diseases (Ene-Obong *et al.,* 2016). Microbial contamination of fruits is mostly responsible for yield losses. Contamination by microorganisms may occur through direct contact with soil, dust, water, and by handling at harvest or during postharvest processing (Eni *et al.,* 2010); they are an easy source of foodborne infection. My team of researchers investigated the implication of fruits and fruit juices in microbiological and nutrition safety. Some of our findings include Oranusi and Braide (2012b); Oranusi, Braide, and Nwankwo (2012); Oranusi, Onibokun, Afolabi, Okpalajiaku, Seweje, Olopade, and Obafemi (2020) as shown in Tables 34, 35 and Figure 16.

Table 34. Mean pH, vitamin C and percentage proximate composition of *C. lepidota* fruits

Sample	pH	Vitamin C (mg 100 mL^{-1})	Moisture	Proteins	Lipids	Crude fibre	Ash	Carbon-hydrate
			(%)					
Endocarp	5.5	6.34	9.29	4.20	2.72	26.18	4.42	53.17
Mesocarp	4.5	14.39	12.31	3.60	2.66	8.18	4.52	68.72
Exocarp	6.7	10.02	10.36	8.13	0.93	15.54	1.23	63.80

Table 35. Mean mineral composition (mg 100g–1) of *C. lepidota* fruits

Sample	Fe	Cu	Zn	Pb	Mn	Cd	Cr
Endocarp	0.0400	0.0070	0.0330	0.0000	0.0120	0.0000	0.0000
Mesocarp	1.4167	0.0698	0.1515	0.3580	0.2013	0.0003	0.0034
Exocarp	1.7930	0.1722	0.2727	0.0151	0.5679	0.0005	0.1343

Fe – Iron; Cu – Copper; Zn – Zinc; Pb – Lead; Mn – Manganese; Cd – Cadmium; Cr – Chromium

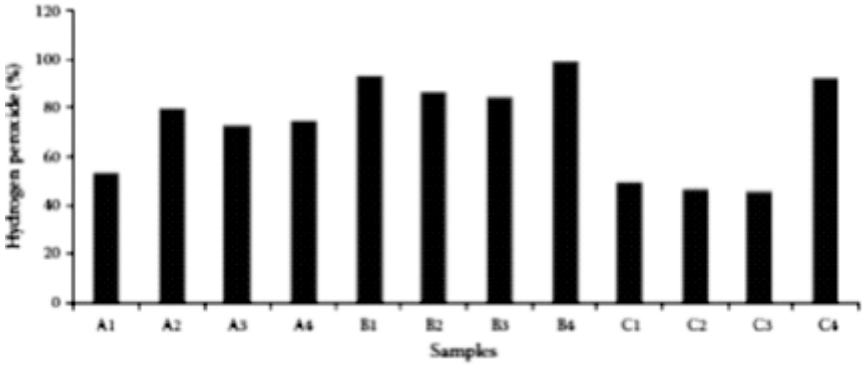

Figure 16: Mean hydrogen peroxide scavenging activity of different parts of C. lepidota fruits A – endocarp; B – exocarp; C – mesocarp; concentrations:1 – 25.000 mg/mL; 2 – 12.500 mg/mL; 3 – 6.250 mg/mL; 4 – 3.125 mg/mL

These studies observed that the different parts of carrot (*Daucus carota*), the eye, between buds, leave stump and body were contaminated; apples (*Malus domestica*) were also contaminated. The report also presented the nutrient and phytochemical compositions, including contaminating microorganisms of *C. lepidota* fruit. The study shows that the *C. lepidota* fruit is rich in essential nutrients, phytochemicals, and vitamin C. *lepidota* therefore, it is suitable for human consumption. All the component parts of *C. lepidota* fruits (endocarp, mesocarp, and exocarp)

presented good antioxidant properties by the hydrogen peroxide scavenging activity. Antioxidants are known to inhibit oxidation and oxidative stress and remove potentially damaging oxidizing agents in a living organism, thus preventing diseases and serious ill-health in man and animals.

Microbiological and chemical quality of some commercially packed fruit juices sold in Nigeria were also assessed by my research team (Oranusi, Braide, and Nezianya, 2012; Onuoha, Oranusi *et al.*, 2018). The results are as presented on Tables 36-38.

Table 36. Total microbial counts (cfu/mL) and microbial isolates of fruit juices

Sample code and type	TAMC	TFC	TCC	Microorganisms isolated
NMKI -Lemon juice	$1.4x10^6$	$1.2 x10^4$	-	*S. aureus, Saccharomyces spp, Bacillus spp*
NGDI -Lemon juice	$6.0x10^6$	$2.3 x10^4$	$2.8 x10^6$	*S. aureus, Enterobacter spp, Rhizopus*
NMKI -Orange juice	$1.9 x10^6$	$4.0 x10^3$	-	*Bacillus spp, Saccharomyces spp*
NLAV -Orange juice	$5.4 x10^6$	$1.4 x10^3$	-	*Staphylococcus, P. caseicolum, Saccharomyces spp*
NDAN -Pineapple juice	$9.6 x10^6$	$4.3 x10^4$	-	*Bacillus spp, Aspergillus spp*
NFAL -Citrus burst	$1.1 x10^5$	$1.0 x10^3$	-	*B. subtils, Penicillium spp, Corynebacterium spp*
NFRN -Orange juice	$1.5 x10^5$	$1.4 x10^3$	-	*Saccharomyces spp, Aspergillus & Penicillium spp*
NCHP - Pineapple juice	$1.8 x10^5$	$1.7 x10^3$	$6.0 x10^4$	*Enterobacter spp, Penicillun spp, Rhizopus*
IRUB -Guava juice	$2.6 x10^5$	$1.6 x10^3$	$1.1 x10^4$	*Streptococcus spp, Bacillus spp, Acetobacter spp*
IARI -Punch juice	$2.1 x10^4$	$1.4 x10^4$	-	*S. aureus, Lactobacillus spp, Aspergillus spp*

TAMC= total aerobic mesophilic count; TFC= total fungal count; TCC= total coliform count; - = no growth; N-begins code of samples manufactured in Nigeria; I-begins code of imported samples

Table 37. Chemical properties of fruit juice

Properties	NMKI Lemon juice	NGDI Lemon juice	NMKI Orange juice	NLAV Orange juice	NDAN Pineapple juice	NFAL Citrus juice	NFRN Orange juice	NCHP Pineapple juice	IRUB Guava juice	IARI Punch juice
Ph	3.62	3.44	3.54	3.44	4.50	4.43	4.43	3.98	3.98	3.20
Titrable acid	0.30	0.34	0.30	0.34	0.19	0.20	0.19	0.19	0.48	0.45
Soluble solid (%)	1.01	1.00	2.80	1.00	11.00	11.40	12.68	13.40	8.60	8.50
Sugar (% sucrose)	11.86	0.30	1.50	0.30	10.80	11.00	9.00	13.00	7.60	7.55
Total solids mg/kg	20.20	2.70	15.30	2.70	22.00	30.00	27.20	26.00	42.35	42.00
Ascorbic acid mg/100ml	77.48	35.22	20.25	35.22	2.60	19.37	35.22	4.64	35.22	25.00
Benzoic acid	15.25	99.12	26.25	99.12	64.00	-	-	62.00	122.00	80.00
Ethyl alcohol	-	-	-	-	-	-	-	-	-	-
Arsenic µ/l	-	-	-	-	-	-	-	-	-	-
Copper µ/l	-	-	-	-	-	-	-	-	-	-
Lead µ/l	-	-	-	-	-	-	-	-	-	-
Fe µ/l	-	-	-	-	-	-	-	-	-	-

- = no growth; N-begins code of samples manufactured in Nigeria; I-begins code of imported samples

Table 38. Percentage Occurrence of Ochratoxin in Multiple and Single Fruit Juices

Sample Code	Ochratoxin
MFA	+
MFB	-
MFC	-
MFD	+
MFE	+
MFF	-
MFG	+
MFH	+
MFI	-
MFJ	-
MFK	-
SFA	+
SFB	-
SFC	-
SFD	-
SFE	-
SFF	+
SFG	-
SFH	+
SFI	-
SFJ	+
Presence percentage	9 (42.9%)

KEYS: MF = Multiple Fruit Juice; SF = Single Fruit Juice
+ = Presence of Ochratoxin; - = Absence of Ochratoxin

The microbiological and chemical qualities of some commercially **packed fruit juices** sold in Nigeria were assessed. Fruit juice samples were collected including Orange, Lemon, Pineapple, Punch, and Guava juice. Samples were screened for total aerobic mesophilic bacterial counts which ranged from $1.4x10^4$ to $2.6x10^5$ cfu/mL. The fungal count ranged from $1.4x10^3$ to $1.7x10^5$ cfu/mL, while the coliform counts ranged from $1.1x10^4$ to $6.0x10^4$ cfu/mL. The isolated microbes include *S. aureus, B. subtilis, P. caseicolum, and species of Saccharomyces, Enterobacter, Corynebacterium, Aspergillus, Rhizopus, Streptococcus, Acetobacter, Staphylococcus, Bacillus,* and *Lactobacillus.* The total microbial counts were within

acceptable standards for human consumption. *Bacillus, S. aureus Saccharomyces and Penicillium* were the most prevalent organisms isolated. All the samples were of acidic pH ranging from 3.20 to 4.50. Titrable acidity was 0.19 to 0.48; sugar (% sucrose) was 0.30 to 13.00. Heavy metals were not detected in any of the samples. The level of bacterial counts, fungal count, and the absence of heavy metals conform to the standard specifications of the National Agency for Food and Drug Administration and Control (NAFDAC) and Standard Organization of Nigeria (SON). The presence of coliforms and ochratoxin in some of the fruit juice calls for strict adherence to GMP and effective HACCP applications.

Oranusi, Oba, Okunola and Okagbue (2018) presented data on microbial and physicochemical assessment of mixed fruit wine produced from physically damaged fruits (Tables 39-41).

Table 39. The microbial counts (cfu/ml) during the fermentation process

Days	TVC	TCC
0	–	–
1	6.0×10^4	0
2	8.5×10^4	0
3	1.6×10^5	0
4	1.95×10^5	0
5	5.5×10^4	0
6	2.5×10^4	0
7	1.6×10^4	0
14	4.0×10^3	0
21	2.0×10^3	0
63	1.0×10^3	0
64	0	0

Remark: Day 28- first week of clarification, Day 42-third week of clarification, Day 56-fifth week of clarification, Day 63-Sixth week of clarification, Day 64- Bottling of wine, TVC- Total viable counts; TCC- Total coliform counts.

Table 40. Changes in alcohol content (%) during the fermentation process

Days	Replicate 1	Replicate 2
0	0	0
1	0.26	0.26
2	0.39	0.39
3	1.17	1.17
4	1.77	1.80
5	2.60	2.60
6	3.50	3.50
7	4.40	4.41
14	4.60	4.60
21	6.18	6.18
28	6.50	6.50
42	6.54	6.60
56	6.60	6.60
63	6.80	6.80
64	6.80	6.80

Remark: Day 28- first week of clarification, Day 42-third week of clarification, Day 56-fifth week of clarification, Day 63-Sixth week of clarification, Day 64- Bottling of wine.

Table 41. Changes in pH during the fermentation process.

Days	Replicate 1	Replicate 2
0	5.73	5.72
1	4.93	4.95
2	4.64	4.63
3	4.55	4.55
4	4.59	4.49
5	4.50	4.50
6	4.49	4.49
7	4.39	4.40
14	4.25	4.27
21	4.10	4.12
28	4.05	4.07
42	4.05	4.03
56	3.96	3.95
63	3.93	3.94
64	3.93	3.93

Remark: Day 28- first week of clarification, Day 42-third week of clarification, Day 56-fifth week of clarification, Day 63-Sixth week of clarification, Day 64- Bottling of wine.

The work presented mixed fruit wine made from physically damaged fruits (watermelon, pineapple, and orange). The total viable plate counts and total coliform counts from the aerobic and anaerobic fermentation process were within acceptable limits as well as the pH, titratable acidity (TTA), specific gravity, alcohol content, and reducing sugar. This is one practical way to reduce food loss and wastes

Microbiological safety evaluation of **street vended ready-to-eat fruits** sold in Ota, Ogun state, Nigeria was conducted by Oranusi

and Olorunfemi (2011). Results are as shown on Table 42.

Table 42. Mean microbial load of ready-to-eat fruit samples

Sample	Local Market			University cafeteria		
	Mean count cfu/ml			Mean count cfu/ml		
	TAPC	TCC	TFC	TAPC	TCC	TFC
Apple	$7.0x10^{6}{}_{a}$	$3.4x10^{6}{}_{a}$	$1.1x10^{3}{}_{a}$	$6.0x10^{4}{}_{e}$	$2.2x10^{3}{}_{a}$	$1.0x10^{3}{}_{a}$
Fruit salad	$3.3x10^{8}{}_{b}$	$2.8x10^{6}{}_{a}$	$5.0x10^{2}{}_{a}$	$2.7x10^{7}{}_{d}$	$2.2x10^{6}{}_{a}$	$1.0x10^{2}{}_{a}$
Pawpaw	$2.1x10^{6}{}_{a}$	$2.0x10^{6}{}_{a}$	$5.0x10^{2}{}_{a}$	$4.8x10^{4}{}_{a}$	$4.2x10^{6}{}_{a}$	$2.0x10^{1}{}_{a}$
Pineapple	$2.0x10^{6}{}_{a}$	$2.0x10^{3}{}_{a}$	$2.0x10^{2}{}_{a}$	$2.0x10^{3}{}_{cf}$	$2.7x10^{6}{}_{a}$	$2.0x10^{2}{}_{a}$
Watermelon	$8.2x10^{8}{}_{b}$	$3.5x10^{6}{}_{a}$	$7.0x10^{2}{}_{a}$	$3.0x10^{6}{}_{a}$	$3.3x10^{6}{}_{a}$	$3.0x10^{2}{}_{a}$

TAPC= Total aerobic plate count TCC= Total coliform count TFC= Total fungal count a, b, c, d, f= Mean within column and row with the same letter for same count are not significantly different ($p>0.05$)

Microbiological safety evaluation of street vended ready-to-eat fruits was conducted in two vending sites, a local market and a university cafeteria. The mean total aerobic plate count ranged from $2.0x10^{6}$ to $8.2x10^{8}$ in pineapple and watermelon obtained from the local market and from $6.0x10^{4}$ to $2.7x10^{7}$ in apple and fruit salads from the university cafeteria. All the samples were contaminated with coliform and fungi. The presence of coliform and counts of $\geq 10^{6}$ in most of the samples is a reflection of the sanitary quality of the processing of the products and calls for concern. Adequate training of food vendors to maintain a high standard of personal and environmental hygiene, proper washing of fruits before consumption, regular washing of hands and effective application of hazard analysis critical control point (HACCP) will help control contamination of products.

My research team experimented on the influence of food fortification on the microbial diversity and physicochemical characteristics of the food. Ahaotu, Anyogu, Obioha, Aririatu, Ibekwe, Oranusi, Sutherland, Ouoba (2017). The influence of soy fortification on cassava fermentation for garri production is as shown on Tables 43 and 44.

Table 43. Effect of fortification with soy products on the chemical composition of garri.

Samples	Parameters						
	Protein (%)	fat (%)	Ash (%)	Moisture (%)	Total cyanide (mg kg^{-1})	pH	Titratable acidity (%)
Control	0.73 ± 0.12^{a}	0.39 ± 0.02^{a}	1.86 ± 0.86^{a}	6.30 ± 0.55^{a}	26.41 ± 9.80^{a}	4.79 ± 1.14^{a}	0.56 ± 0.00^{a}
MSF	10.17 ± 0.44^{b}	4.13 ± 0.09^{b}	1.90 ± 0.42^{ab}	5.56 ± 0.61^{a}	11.08 ± 3.91^{b}	4.96 ± 0.90^{a}	0.63 ± 0.00^{b}
SP	10.05 ± 2.02^{b}	1.17 ± 2.91^{b}	2.09 ± 0.64^{b}	6.30 ± 0.69^{a}	11.02 ± 2.52^{b}	5.16 ± 0.60^{a}	0.61 ± 0.00^{b}

Values represent means of duplicate experiments ± standard deviations. Values with the same superscript in a column are not significantly different ($p < 0.05$).
Keys: Control = Unfortified, MSF = Malted soy flour, SP = Soy protein.

Table 44. Sensory attributes of eba produced from soy-fortified garri.

Sample/Time of fermentation	Texture	Colour	Aroma	Bolus formation	General acceptability
Control/0 h	6.70 ± 1.66^{a}	6.80 ± 2.06^{a}	7.95 ± 1.05^{a}	7.30 ± 2.06^{a}	6.85 ± 1.76^{a}
Control/24 h	6.55 ± 1.88^{a}	6.45 ± 1.24^{a}	5.30 ± 1.95^{b}	5.40 ± 1.79^{b}	5.85 ± 1.60^{b}
Control/48 h	7.25 ± 1.62^{a}	6.80 ± 1.96^{a}	7.30 ± 1.38^{a}	7.30 ± 1.26^{a}	7.40 ± 1.60^{a}
Control/72 h	7.70 ± 1.38^{a}	7.20 ± 1.94^{a}	7.50 ± 1.15^{a}	7.25 ± 1.59^{a}	7.50 ± 1.47^{a}
MSF/0 h	6.05 ± 2.21^{b}	5.55 ± 1.93^{b}	5.20 ± 1.96^{b}	6.35 ± 1.95^{a}	6.10 ± 1.92^{b}
MSF/24 h	6.00 ± 2.00^{b}	5.80 ± 2.09^{b}	4.55 ± 2.33^{b}	6.00 ± 1.86^{a}	5.70 ± 1.87^{b}
MSF/48 h	7.55 ± 1.51^{a}	6.95 ± 1.64^{a}	5.35 ± 2.03^{b}	6.35 ± 2.06^{a}	6.55 ± 1.73^{b}
MSF/72 h	7.45 ± 1.61^{a}	6.75 ± 1.62^{a}	5.20 ± 2.07^{b}	6.05 ± 1.93^{a}	6.40 ± 1.54^{b}
SP/0 h	7.20 ± 1.61^{a}	6.75 ± 1.59^{a}	6.40 ± 1.96^{a}	6.35 ± 1.84^{a}	6.45 ± 1.57^{a}
SP/24 h	6.80 ± 2.08^{a}	7.05 ± 1.23^{a}	6.95 ± 1.45^{a}	6.50 ± 1.88^{a}	6.85 ± 1.42^{a}
SP/48 h	7.25 ± 1.65^{a}	7.40 ± 1.26^{a}	6.95 ± 1.23^{a}	7.00 ± 1.59^{a}	7.15 ± 1.69^{a}
SP/72 h	7.65 ± 1.27^{a}	7.00 ± 1.49^{a}	6.35 ± 1.70^{a}	6.40 ± 1.76^{a}	6.75 ± 1.77^{a}

Values are means ± standard deviation of twenty panellists. Values with the same superscript in a column are not significantly different ($p < 0.05$).
Keys: Control = Garri made from unfortified cassava mash; MSF = Malted soy flour; SP = Soy protein; 0 h, 24 h, 48 h, 72 h = Time of cassava fermentation before garrification.

This study investigated the influence of the addition of soy products on the microbiology, nutritional and physico-chemical characteristics of garri, a fermented cassava product. The protein content of soy-fortified garri increased from 0.73% to 10.17% and 10.05% in MSF and SP garri respectively with a significant decrease in total cyanide from 26 to 11 ppm. Results from physicochemical and organoleptic evaluation indicated that supplementation of cassava with soy products prior to fermentation produced acceptable garri. After further work on the pasting properties of this product, two years after this research, Soy fortified garri is in the Nigerian market today.

9.5 Fresh/Raw Foods

The quality of food raw materials often determine/influence the quality of the final product. Manufacturers normally will select good quality materials for their production, because the cost of treatments

to upgrade raw material deficiency is enormous. My research team evaluated the qualities of some raw materials. Olopade, Oranusi, Nwinyi, Njobeh and Lawal (2019) investigated the modification of montmorillonite clay with *Cymbopogon citratus* for the decontamination of zearalenone in millet. Results are as presented in Figures 17 and 18.

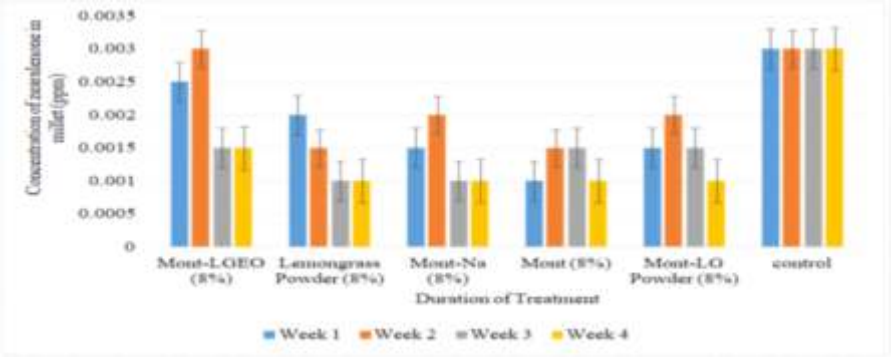

Figure 17: Evaluation of zearalenone level after treatment with 8% of nanoformulations.

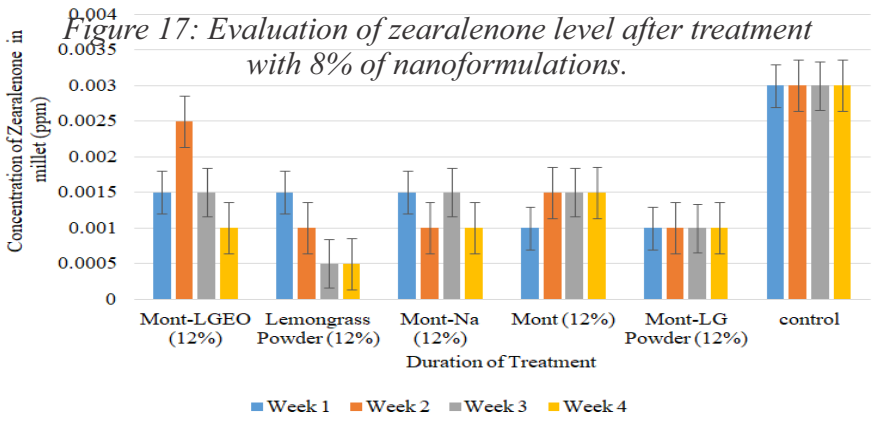

Figure 18: Evaluation of zearalenone level after treatment with 12% of nanoformulations.

Montmorillonite clay due to its abundance and environmental friendliness has several industrial applications among which is the adsorption of mycotoxins in foods and feeds as binding agents. Fungal species from the genus *Fusarium* produce zearalenone (ZEA); an oestrogenic compound, which has been implicated in

hormonal and reproductive issues for both animals and man. In this study, various nanoformulations from montmorillonite clay and *Cymbopogon citratus* (lemongrass) extracts were developed for the decontamination of ZEA in millet. All the formulations were effective in the decontamination of ZEA in millet after 4 weeks with Lemongrass powder (LGP) exposed at 12% recording the highest reduction of 98.3% while the second most effective formulation, Mont-LGP exposed at 12% showed a 66% reduction of ZEA in millet ($p = 0.05$). The organo-cations complex in lemongrass powder could be responsible for this effectiveness in the adsorption of ZEA in millet. The use of Mont-LGP and LGP can thus serve as a sustainable intervention for the decontamination of ZEA in stored cereals especially as the method is cost-effective, user-friendly, and easy to disseminate for use in both the food and feed industries.

Oranusi, Nwankwo, Onu-Okpara, and Olopade (2016), assessed grains sold in Nigerian Markets, for Micro Flora, Deoxynivalenol (Don), and Fumonisin Contamination, and result is presented in Table 45.

Table 45. Mean microbial count (cfu/g) and assay for Fumonisin and DON (mg/kg)

Outlet/ Sample		Fungal count	Total aerobic Plat count	Coliform count	Fumonisin ≥4.0 mg/kg	DON ≥1.25 mg/kg
Outlet 1						
1)	Sorghum	5.0×10^{4}	3.0×10^{6}	1.2×10^{2}	-	-
2)	Maize	3.7×10^{5}	2.7×10^{5}	1.0×10^{2}	+	-
3)	Millet	3.6×10^{5}	2.0×10^{5}	NG	-	-
4)	Wheat	5.0×10^{5}	2.4×10^{6}	NG	-	+
Outlet 2						
5)	Sorghum	8.0×10^{5}	5.6×10^{6}	NG	-	-
6)	Maize	4.6×10^{5}	5.0×10^{5}	NG	+	-
7)	Millet	3.8×10^{5}	3.7×10^{5}	NG	-	-
8)	Wheat	5.3×10^{5}	2.4×10^{6}	1.1×10^{1}	-	+
Outlet 3						
9)	Sorghum	3.0×10^{4}	3.4×10^{6}	1.3×10^{3}	-	-
10)	Maize	3.5×10^{5}	3.5×10^{5}	NG	+	-
11)	Millet	1.5×10^{5}	3.2×10^{5}	NG	-	-
12)	Wheat	4.0×10^{4}	9.0×10^{6}	NG	-	+
Outlet 4						
13)	Sorghum	1.5×10^{5}	3.2×10^{6}	2.0×10^{3}	-	-
14)	Maize	3.3×10^{5}	7.0×10^{6}	NG	+	-
15)	Millet	5.0×10^{5}	4.0×10^{6}	NG	-	-
16)	Wheat	5.0×10^{5}	8.3×10^{5}	NG	-	+
Outlet 5						
17)	Sorghum	2.0×10^{5}	4.8×10^{6}	NG	-	-
18)	Maize	1.1×10^{5}	3.3×10^{6}	NG	+	-
19)	Millet	2.0×10^{5}	6.5×10^{5}	NG	-	-
20)	Wheat	4.5×10^{5}	5.4×10^{5}	NG	-	+

Fumonisin at concentration ≥4.0 mg/kg (ppm) was detected in eight samples of *Zea mays* and two samples of *Triticum aestivum* while DON at concentrations ≥1.25 mg/kg (ppm) was detected in all the wheat samples using the Rida® Quick Fumonisin and DON test kits. Infection of grains by fungal species and contamination with mycotoxins can generally be influenced by favourable weather conditions. Measures to address climate changes, effective HACCP, and good storage systems are advocated to prevent mould contamination and deleterious mycotoxin production in grains.

A study on the Microbial, Proximate, and Heavy Metal Compositions of some Gastropods, Bivalve, and Crustacean seafood was conducted by Oranusi, Effiong, and Duru (2018). The result is shown in Tables 46 and 47.

Table 46. Mean microbial count (cfu/g) of the seafood samples

Sample	TAPC	TCC	TFC
Littorina littorea	$4.3 \times 10^7 \pm 2.05^b$	$3.9 \times 10^6 \pm 1.01^f$	$3.0 \times 10^6 \pm 1.02^a$
Achatina fulica	$2.0 \times 10^8 \pm 1.50^a$	$1.0 \times 10^6 \pm 2.04^g$	$1.0 \times 10^5 \pm 0.02^d$
Tympanotonus fuscatus	$3.0 \times 10^8 \pm 2.23^a$	$2.0 \times 10^6 \pm 1.64^h$	$2.0 \times 10^6 \pm 1.84^a$
Dorsanum minax	$1.3 \times 10^7 \pm 2.64^b$	$1.5 \times 10^6 \pm 1.00^h$	$1.1 \times 10^5 \pm 0.84^b$
Egeria radiata	$4.0 \times 10^4 \pm 0.05^e$	$1.0 \times 10^6 \pm 0.54^g$	$2.0 \times 10^4 \pm 0.03^e$
Penaeus notialis	$9.2 \times 10^3 \pm 1.04^g$	$2.5 \times 10^6 \pm 0.06^h$	$1.4 \times 10^5 \pm 0.34^b$

KEY: TAPC= Total Aerobic plate count, TCC = Total coliform count, TFC =Total fungal count. Super script checked the counts with different superscript for the same count (within the same column) are significantly different

Table 47. Percentage (%) proximate composition of seafood

SAMPLE	Moisture	Protein	Lipid	Ash	Fibre	Total carbohydrate	Total solid (dry matter)	Organic matter
Littorina littorea	51.80±2.04^a	8.0±0.03^a	4.18±0.05^a	19.80±0.22^a	8.48±2.05^a	1.94±1.05^a	48.20±0.05^a	80.20±2.34^a
Achatina fulica	55.10±3.05^a	32.0±0.01^b	4.77±0.23^a	4.21±0.68^b	7.08±1.01^a	2.52±1.04^a	44.90±1.44^a	95.79±1.02^b
Tympanotonus fuscatus	74.80±2.02^b	27.0±0.02^b	5.20±0.08^a	4.16±0.60^b	2.88±0.05^b	2.67±1.03^a	25.20±0.98^b	95.84±1.00^b
Dorsanum minax	68.80±1.22^a	43.0±0.05^c	8.80±1.00^c	12.71±1.05^c	4.00±0.05^b	1.32±0.23^a	31.20±0.08^a	87.29±1.66^a
Egeria radiata	75.50±2.04^b	46.0±0.03^c	4.57±0.08^a	4.79±1.01^b	9.96±0.66^a	1.18±0.84^a	24.50±0.52^b	95.21±0.10^b
Penaeus notialis	74.50±1.01^b	46.0±0.02^c	0.60±0.01^b	5.36±0.54^b	3.83±1.01^b	3.81±0.86^a	25.50±0.06^b	94.64±2.02^b

Super script abc= values with different superscript for the same parameter (within the same column) are significantly different

The study showed that the heavy metal compositions of the seafood were generally low except for manganese 6.36±0.03 ppm in *Dorsanum miran* and nickel 0.81±0.50 ppm in *Penaeus notialis*. The microbial loads of the seafood were significantly ($p \leq 0.05$) higher in gastropods and more than acceptable standards. Effective protection of water bodies for food cultivation and constant monitoring of seafood is necessary. Adequate processing and employing good manufacturing practices can reduce the microbial loads to an acceptable level and prevent food-borne hazards that could be associated with seafood consumption.

Oranusi, Obioha and Adekeye (2014) investigated the microbial profile of frozen fish and meat, and the findings are shown in Tables 48 and 49.

Table 48. Mean microbial count log10 (cfu/g) of frozen meat samples

Sample	TAPC	Coliform Count	Fungi Count
Poultry- Chicken	8.67±2.09	5.10±0.91	3.36±0.72
Poultry- Turkey	7.69±0.19	3.84±0.51	3.36±0.61
Gizzard	9.46±1.32	6.70±0.31	3.34±0.24

Table 49. Mean microbial count log10 (cfu/g) of frozen fish samples

Microbial count	Sampling sites		
	Head region	Intestinal region	Skin
Trachurus trachurus (Kote`)			
TAPC	11.07±1.21	9.46±0.29	4.59±0.39
Coliform count	5.17±0.65	-	5.69±0.85
Fungal count	4.15±0.46	1.49±0.01	3.66±0.42
Scomber scombrus (Titus or Scombia)			
TAPC	7.11±1.31	10.67±1.23	4.63±0.43
Coliform count	3.74±0.42	-	4.30±0.11
Fungal count	2.87±0.32	1.36±0.02	3.63±0.34
Urophycis tennis (Stock fish)			
TAPC	8.93±0.54	11.82±2.11	6.79±0.32
Coliform count	5.92±0.46	2.43±0.72	4.45±0.42
Fungal count	5.08±0.18	3.36±1.33	3.56±0.52
Clupea harengus (Sawa or Shawa)			
TAPC	11.97±1.32	9.92±0.84	4.58±0.91
Coliform count	2.65±0.03	0.90±0.00	3.18±0.62
Fungal count	4.96±0.78	2.85±0.12	3.58±0.98

Freezing preserves food by stopping the growth and multiplication of microbes or by halting the food's own enzyme activity that would otherwise cause the food to rot. There have been reports of illness involving frozen foods due to post-harvest contamination. This study investigated the microbial profile of frozen fish and meat. Coliforms were detected in all the meat samples, the presence of coliform calls for concern because this group indicates the possibility that disease organisms may also be present in the meat and fish samples (Silliker and Gabis, 1976; Rompre *et al., 2002;* Environmental fact sheet, 2010). Though the raw meat and fish can become well processed before consumption, cross-contamination of other products eaten raw or with minimal processing can be very challenging.

Eni, Oluwawemitan and Oranusi (2010), examined the microbial quality of fruits and vegetables sold in Sango Ota, Nigeria. The report is indicated in Table 50 and Figure 19.

Table 50. Total plate count of 15 fruits and vegetable sampled in Sango Ota, Nigeria.

Fruit sample	Microbial load (cfu/ml)		
	Vendor A	Vendor B	Vendor C
Carrot	3.8×10^6	2.9×10^7	7.8×10^6
Runner beans	9.1×10^6	9.9×10^6	NT
Cucumber	1.3×10^7	NT	4.6×10^6
Pineapple	1.3×10^6	NT	3.0×10^7
Green Pepper	3.6×10^6	NT	NT
Cabbage	1.8×10^7	NT	NT
Spring Onions	NT	3.0×10^7	NT
Lettuce	NT	1.7×10^7	NT
Water Melon	NT	NT	1.0×10^7
Apple	NT	NT	9.0×10^5

NT- Not tested.

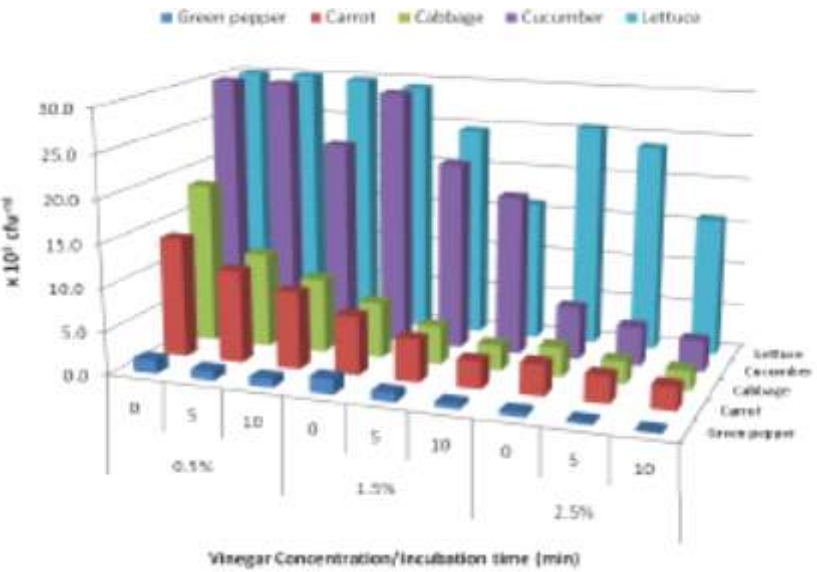

Figure 19: *Effect of vinegar concentration (0.5-2.5%) and exposure time (0-10 min) on microbial loads of five vegetables sampled in Sango Ota, Nigeria.*

Fresh fruits and vegetables promote good health but harbour a wide range of microbial contaminants. All the fruits and vegetables sampled in this study were contaminated. However, the microbial load of the fruits and vegetables varied with type and vendor. Apple from vendor C had the lowest microbial load (9×10^5 cfu/mL) of all the fruits and vegetables sampled, while spring onions from vendor B and pineapple from vendor C had the highest microbial load (3.0×10^7 cfu/mL). In the ready-to-eat sliced fruits sampled in this study, pineapple from vendor A had the least microbial load (1.3×10^6 cfu/mL) while pineapple from vendor C had the highest microbial load (3.0×10^7 cfu/mL). The effect of acetic acid (vinegar) concentration (0.5 - 2.5%) and exposure time (0-10 min) on the microbial load of five vegetables were also assessed. Increasing vinegar concentration from 0.5 - 2.5% reduced microbial loads by 15 - 82%. The least microbial loads for all vegetables were obtained when exposed to 2.5% vinegar solution for 10 min. Consumer awareness of the dangers of consuming pathogen-contaminated

foods and the need to insist on properly processed/stored sliced produce needs to be reawakened.

Olopade, Oranusi, Nwinyi, Gbashi, Njobeh (2021), investigated the ooccurrences of Deoxynivalenol, Zearalenone, and some of their masked forms in selected cereals from Southwest Nigeria. We observed that the levels of ZEN in maize and sorghum samples were lower than the maximum limit of 100 μg/kg set by the European Union for ZEN. However, two millet samples exceeded this limit with concentrations of 152 and 396 μg/kg (Figures 20a-c). The percentage incidence for α-ZEL was 100% for maize, sorghum, and millet samples while the percentage incidence of β-ZEL was 100% for maize and millet and 95% for sorghum samples. Regardless of the low levels of these mycotoxins, particularly DON, the high incidence rates are of concern, as there could be synergistic or additive effects from ZEN and its masked forms. Effective harvesting and storage of grains is key to reducing moulds and mycotoxins. Decontamination of grains of mycotoxins before use will be a measure for safe food.

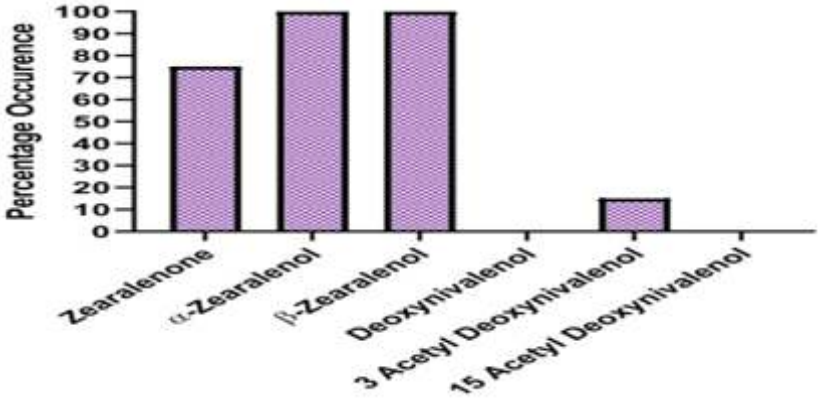

Figure 20a: Percentage of DON, ZEN, and their masked forms in maize samples from Southwest Nigeria.

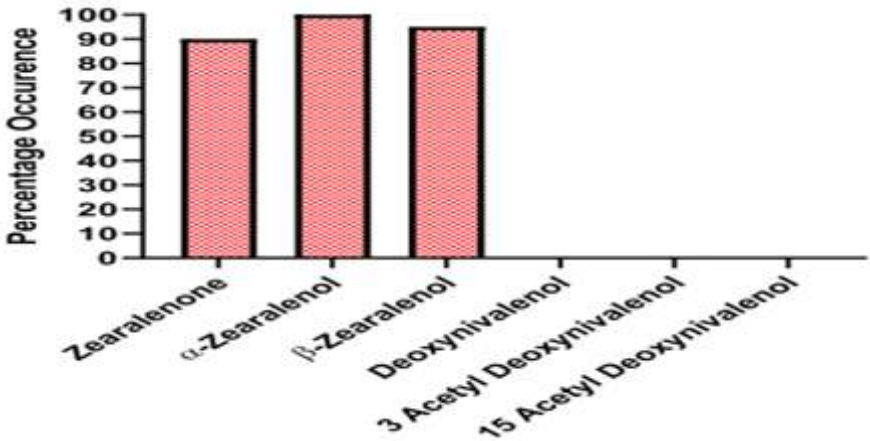

Figure 20b: Percentage of DON, ZEN, and their masked forms in sorghum samples from Southwest Nigeria.

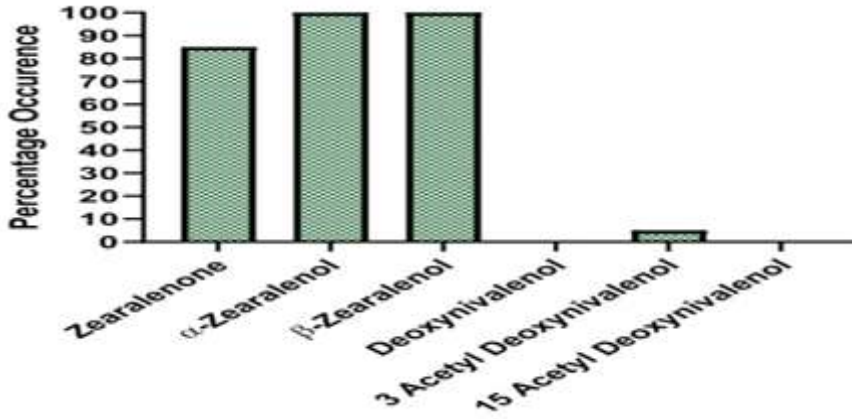

Figure 20c: Percentage of DON, ZEN, and their masked forms in millet samples from Southwest Nigeria.

9.6 Water and Drinks

Water is indispensable in the processing of foods; the quality and quantity of available water have implications on the health status of a community. According to the UN report, more than 5 million people

die annually from diseases caused by drinking contaminated water and lack of adequate sanitation. One of the Sustainable Development Goals (SDGs) of the United Nations (UN) is improved water quality (Owamah et *al.,* 2013). The provision of potable water is necessary to prevent water and food-borne diseases (Okorafor et *al.,* 2012). Dahunsi, Owamah, Ayandiran and Oranusi (2013) examined the drinking-water quality and public health of selected towns in South-Western Nigeria (Tables 51 and 52).

Table 51. Microbial profile of the water samples in the area of study

Sample	Total aerobic plate count (cfu 100 mL^{-1})	Total coliform count (cfu 100 mL^{-1})	*E. coli* (cfu 100 mL^{-1})
Sagamu			
Bore-hole ($n = 45$)	8.00 ± 1.00	ND	ND
Hand-pump well ($n = 40$)	**116.00 ± 2.00**	5.00 ± 1.00	**11.00 ± 1.00**
Hand-dug well ($n = 60$)	2.00 ± 1.00	ND	ND
Mosimi			
Bore hole ($n = 60$)	**135.00 ± 1.00**	ND	ND
Hand-pump ($n = 50$)	13.00 ± 1.00	ND	ND
Hand-dug well ($n = 50$)	**136.00 ± 1.00**	**6.00 ± 1.00**	**8.00 ± 1.00**
Ogijo			
Bore hole ($n = 80$)	12.00 ± 1.00	ND	ND
Hand-pump well ($n = 65$)	82.00 ± 1.00	ND	ND
Hand-dug well ($n = 90$)	**102.00 ± 1.00**	**15.00 ± 1.00**	**10.00 ± 1.00**
Odogunyan			
Bore hole ($n = 75$)	12.00 ± 1.00	ND	ND
Hand-pump well ($n = 80$)	52.00 ± 1.00	**6.2.00 ± 1.00**	**8.00 ± 1.00**
Hand dug well ($n = 70$)	43.00 ± 1.00	**7.00 ± 1.00**	**11.00 ± 1.00**

Results are expressed as mean ± standard deviation, values that exceed standard limits are highlighted ND not detected

Table 52. The mean concentrations of dissolved heavy metals (mg/L) of water samples in the area of study

Sample	Lead (Pb)	Iron (Fe)	Copper (Cu)	Zinc (Zn)	Nickel (Ni)	Total Chromium (Cr)	Cadmium (Cd)
Sagamu							
Bore hole ($n = 45$)	**0.18 ± 0.01**	0.04 ± 0.02	0.02 ± 0.01	0.28 ± 0.02	**0.48 ± 0.02**	**0.26 ± 0.02**	**1.14 ± 0.05**
Hand-pump well ($n = 40$)	**0.15 ± 0.04**	0.02 ± 0.01	0.24 ± 0.01	0.07 ± 0.02	**0.46 ± 0.03**	**0.24 ± 0.03**	**1.09 ± 0.01**
Hand-dug well ($n = 60$)	0.04 ± 0.04	0.02 ± 0.01	0.08 ± 0.02	0.05 ± 0.01	**0.44 ± 0.02**	**0.35 ± 0.03**	**1.12 ± 0.06**
Mosimi							
Bore hole ($n = 60$)	**0.23 ± 0.04**	0.08 ± 0.02	0.09 ± 0.02	0.07 ± 0.02	**0.64 ± 0.03**	**0.27 ± 0.01**	**1.55 ± 0.02**
Hand-pump well ($n = 50$)	**0.25 ± 0.02**	0.09 ± 0.02	0.11 ± 0.02	0.06 ± 0.03	**1.27 ± 0.03**	**0.41 ± 0.01**	**3.11 ± 0.02**
Hand-dug well ($n = 50$)	**0.28 ± 0.02**	0.09 ± 0.02	0.12 ± 0.02	0.06 ± 0.02	**0.46 ± 0.04**	**0.36 ± 0.03**	**1.10 ± 0.02**
Ogijo							
Bore hole ($n = 80$)	**0.26 ± 0.03**	0.04 ± 0.01	0.04 ± 0.01	0.07 ± 0.02	**0.74 ± 0.03**	**0.41 ± 0.01**	**1.74 ± 0.05**
Hand-pump well ($n = 65$)	**0.29 ± 0.02**	0.08 ± 0.02	0.07 ± 0.01	0.28 ± 0.02	**2.77 ± 0.03**	**2.59 ± 0.02**	**3.30 ± 0.43**
Hand-dug well ($n = 90$)	**0.28 ± 0.04**	0.06 ± 0.01	0.09 ± 0.01	0.25 ± 0.02	**1.23 ± 0.01**	**2.22 ± 0.39**	**4.09 ± 0.66**
Odogunyan							
Bore hole ($n = 75$)	**0.16 ± 0.01**	0.09 ± 0.01	0.03 ± 0.02	0.11 ± 0.01	**0.81 ± 0.01**	**1.12 ± 0.03**	**1.09 ± 0.03**
Hand-pump well ($n = 80$)	**0.24 ± 0.03**	0.10 ± 0.02	0.07 ± 0.02	0.12 ± 0.01	**0.90 ± 0.01**	**0.90 ± 0.03**	**0.76 ± 0.02**
Hand-dug well ($n = 70$)	**0.19 ± 0.01**	0.06 ± 0.01	0.08 ± 0.01	0.10 ± 0.01	**0.54 ± 0.02**	**0.59 ± 0.01**	**1.26 ± 0.03**

Results are expressed as mean ± standard deviation, values that exceed standard limits are highlighted

In this study, groundwater samples from bore-holes, hand-pump, and hand-dug wells of four densely populated towns in South-Western Nigeria were analysed with respect to physicochemical factors, biological factors, and the metals Nickel (Ni), Lead (Pb), Cadmium (Cd), Zinc (Zn), Copper (Cu), and Iron (Fe) for six consecutive months from September 2012 to February 2013 to give mean values for each town and water source. Total aerobic plate count, total coliform bacteria, and *E. coli* were detected in most of the water samples from the different towns and sources considered. Except for total suspended solids and total solids, the physicochemical parameters of all the samples were within permissible limits. The concentrations Pb, Ni, Cr, and Cd were above the minimum permissible limits. The presence of coliforms and *E. coli* in the groundwater samples indicates fecal contamination. The microorganisms isolated in this study include Enterobacteriaceae, *Staphylococcus aureus, E. coli, Citrobacter, Klebsiella, Pseudomonas, Bacillus,* and *Micrococcus* species. The analysis of the variance of data obtained from this study shows that

bore-hole water samples were safer for drinking than water samples from hand-pump and hand-dug wells across the communities.

Okunola, Oba, Oranusi, and Okagbue (2018) provided data on microbial assessment and physicochemical characteristics of sachet water samples obtained from three factories in Ota, Ogun State, Nigeria (Tables 53 and 54).

Table 53. Microbial count of sachet water from brand A

Samples	Total plate count (Cfu/ml)	Count on *Salmonella*- *Shigella* agar (Cfu/ml)	Total Coliform count (Cfu/ml)
NIS	–	–	10
WHO Standard	–	–	10
A1	1.6×10^2	3×10^1	5×10^2
A2	9×10^1	NG	NG
A3	1.2×10^2	2×10^1	4×10^1
A4	1.7×10^2	NG	1×10^1
A5	1.1×10^2	1×10^1	NG
A6	1.6×10^2	3×10^1	5×10^1
A7	9×10^1	NG	1×10^1
A8	1.5×10^2	NG	NG
A9	8×10^1	1×10^1	NG
A10	1.3×10^2	2×10^1	NG
A11	1.3×10^2	NG	3×10^1
A12	6×10^1	NG	2×10^1
A13	1×10^1	NG	NG
A14	1.2×10^2	4×10^1	2×10^1
A15	5×10^1	NG	NG
A16	9×10^1	3×10^1	4×10^1
A17	1.1×10^2	NG	3×10^1
A18	NG	NG	NG
A19	9×10^1	4×10^1	2×10^1
A20	1.5×10^2	NG	5×10^1
Mean	1.0×10^2	1.1×10^1	1.8×10^1
Standard Deviation	4.7×10^1	1.5×10^1	1.9×10^1

NG: No growth, NIS: Nigeria Industrial Standards, WHO: World Health Organizations.

Table 54. Physicochemical analysis of sachet water from brands A, B and C.

Parameters (mg/L)	A	B	C	NIS	WHO
Aluminium	ND	ND	ND	0.2	0.2
Calcium Hardness	ND	ND	ND	–	–
Chloride	0	0	0.3, 0.3, 0.5	250	250
Dissolve oxygen	0	0	0.01, 0.02.0.02	–	6
Fluoride	ND	ND	ND	1.5	1.5
Free chlorine	0	0.05,0.04, 0.06	0.06, 0.07.0.07	0.2–0.025	0.2
Iron	0	0	ND	0.3	0.3
Magnesium	ND	0	ND	0.20	0.20
Manganese	ND	0	ND	0.2	0.2
Nitrite	0	0	0	0.2	0.2
Phosphate	0	0	ND	–	3.50
Potassium	0.3, 0.3, 0.2	0	0.2, 0.2, 0.2	–	–
Sulphate	4.0, 3.8, 4.2	0	3.0, 3.1.3.1	–	0.002
Total Alkalinity($CaCO_3$)	ND	ND	ND	–	–
Total Chlorine	0	0.004, 0.03,0.02	0.05, 0.06.0.05	–	–
Total Copper	0.02, 0.03, 0.02	0	0.2, 0.1, 0.2	–	2
Total Hardness	ND	ND	ND	–	500
Total Nickel	ND	0	0.5, 0.3, 0.5	0.02	0.02
Total Phosphorus	ND	0	0.12, 0.10, 0.13	–	–
Turbidity (NTU)	4.0, 4.0, 4.3	0	4.0, 4.0, 4.2		5
Zinc	ND	ND	ND	3	–

ND: Not Detected, NIS: Nigeria Industrial Standards, WHO: World Health Organizations.

The study investigated the bacteriological and physicochemical properties of packaged sachet water sold for public consumption. It revealed that the sampled water fell short of microbiological quality specified by the Nigeria Industrial Standards (NIS), and World Health Organization (WHO). The water physicochemical properties were, however, within expected standard. Adequate monitoring of water factories for compliance with standards is advocated.

Oranusi, Madu, Braide, and Oguoma (2011), investigated the safety and probiotic potentials of yogurts sold in Nigeria. They observed that the yogurt producing companies provide information such as batch number, manufacturers address, NAFDAC number, but they do not give information on microbial composition/contents. No pathogens were isolated from the samples investigated (Table 55), and the isolates were found to exhibit some probiotic potentials. It is recommended that strains of microorganisms that can deliver full probiotic potentials to consumers be used in commercial yogurt production and constant monitoring is necessary.

Table 55. Mean total count and colonial characteristics of isolates on BHI and MRS agar

Sample code	Mean total count cfu/ml	Colony code	Size (mm)	Shape	Elevation	Margin	Colour	Surface appearance
				BHI medium				
YGA	3.0×10^7	A_1	5	Regular	Low convex	Entire	Cream	Moist, shiny and mucoid
		A_2	<1	Regular	Low convex	Entire	Yellow	Moist and shiny
YGB	5.0×10^7	B_1	1	Regular	Low convex	Entire	Cream	Moist and shiny
		B_2	<1	Regular	Low convex	Entire	Yellow	Moist and shiny
YGC	2.0×10^7	C_1	3	Regular	Low convex	Entire	Cream	Moist and shiny
		C_2	<1	Regular	Low convex	Entire	Yellow	Moist and shiny
YGD	6.0×10^6	D_1	8	Regular	Low convex	Entire	Cream	Moist, shiny and mucoid
		D_2	2	Regular	Low convex	Entire	Yellow	Moist and shiny
YGE	5.0×10^6	E_1	<1	Regular	Low convex	Entire	Cream	Moist and shiny
		E_2	6	Regular	Low convex	Entire	Yellow	Moist and shiny
				MRS medium				
YGA	2.0×10^8	A	4	Regular	Flat	Entire	Cream	Mucoid and dry
YGB	1.0×10^8	B	3	Regular	Low convex	Entire	Cream	Moist and shiny
YGC	5.0×10^8	C	5	Regular	Flat	Entire	Cream	Moist and shiny
YGD	5.4×10^8	D	3	Regular	Low convex	Serrated	Cream	Moist and shiny
YGE	NO GROWTH	-	-	-	-	-	-	-

Key: YGA = SUPER SUNNEX YG B = GARDEN CITY YGC = G T YG D = JOSSY YG E = KYLIN.

9.7 Food wastes management

Management of food waste is a critical component of safe food. Wastes not properly managed constitute a safety challenge to the environment and compromise food quality and safety. My research team investigated some potential efficient and cost-effective food waste management systems. Some are as highlighted (Braide, Kanu, Oranusi and Adeleye, 2016; Dahunsi, Oranusi and Efeovbokhan, 2017; Onu-Okpara, Oranusi, and Okagbue, 2019).

Onu-Okpara, Oranusi, and Okagbue (2019) worked on the production of probiotic-fortified composite poultry feed from food and agricultural waste material. The objective of the study was to ascertain the feasibility of fortifying composite poultry feed from food and agricultural waste material with the probiotic organism *Lactobacillus fermentum* and determine the efficiency of formulated probiotic-fortified feed via animal feeding tests (Table 56 and Figures 21a-c).

Table 56. Results of proximate analysis value of dried food and agricultural waste samples (average mean)

Item	Moisture content (%)	Ash content (%)	Crude fat (%)	Protein (%)	Crude fiber (%)	Non-fat extract/ Carbohydrates (%)
Food waste	0.73	4.50	16.52	1.20	0.12	76.93
Corn husks	0.50	1.86	4.11	4.50	21.45	67.58
Yam peels	2.19	4.80	3.12	3.80	7.12	78.97
Plantain peels	0.14	2.80	8.10	11.0	3.58	74.38

Probiotic-fortified feed (G3) was formulated using proximate analysis values of waste materials. Alternative diets were G1—Feed Mill of Nigeria starter mash and G2—Ground corn. For the growth comparison test, 30 1-day-old Agricol broiler chicks were randomized into three groups of 10 chicks with each group being placed on a separate diet (G1, G2, and G3). Probiotics antimicrobial efficacy feeding assay consisted of the treatment diets

T1—Feed Mill of Nigeria starter mash and T2—probiotic-fortified feed. Twenty 1-day-old unvaccinated chicks were placed into two groups of 10 chicks each and fed 0.5 mL of 9.0 × 108 CFU/mL *Escherichia coli* 0157:H7 on day 1 after which they were placed on treatment diets. Data collected were analysed and interpreted using the SPSS Statistical tool version 25. Chicks fed G1 and G3 diets performed similarly ($p < 0.05$) in terms of measured parameters (weight, height, and wingspan) and had better performance compared to chicks on G2. In the *E. coli* treatment group, chicks placed on treatment diets T1 and T2 showed similar levels of *E. coli* cell reduction every week. Performance-based on measured parameters was also similar ($p < 0.05$). The feasibility of fortifying composite animal feed with the probiotic organism *L. fermentum* was ascertained and the efficiency of the feed via animal feeding tests was proven.

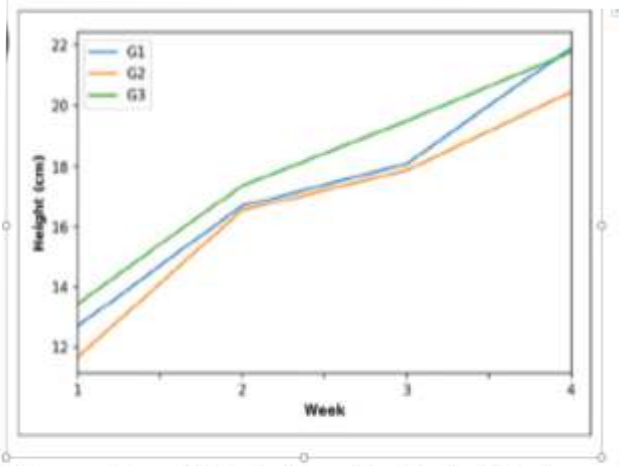

Figure 21a: Effect of probiotic fortified feed weight on height of the broiler

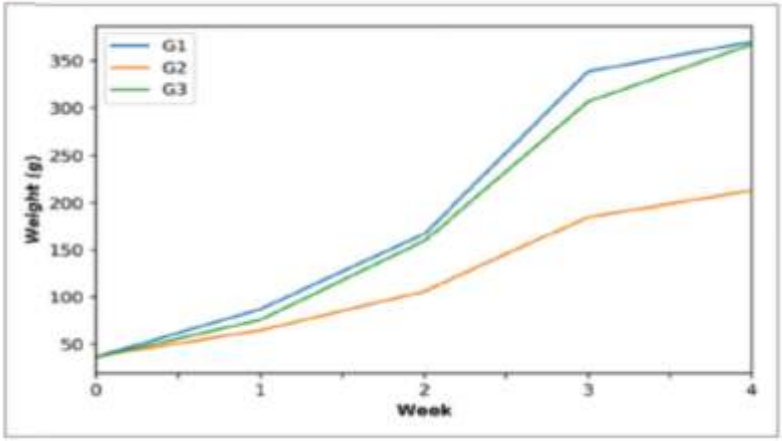

Figure 21b: Effect of probiotic fortified feed on of the broiler

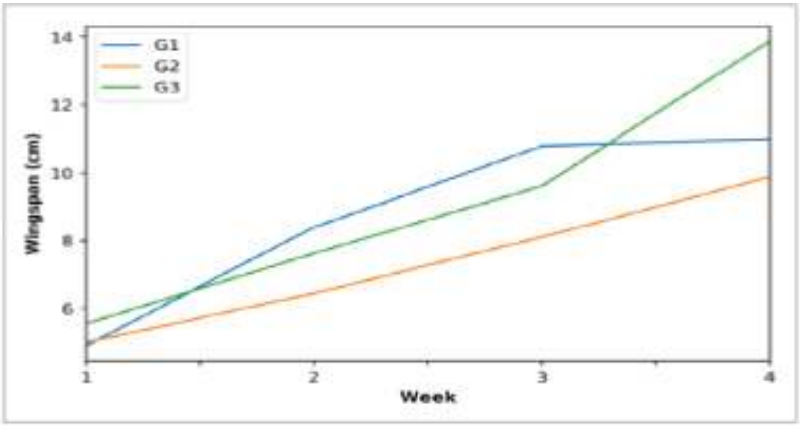

Figure 21c: Effect of probiotic fortified feed on the wing span of the broiler

My research team also investigated the Bio-conversion of *Tithonia diversifolia* (Mexican Sunflower) and Poultry Droppings for Energy Generation with the result as shown in Figure 22.

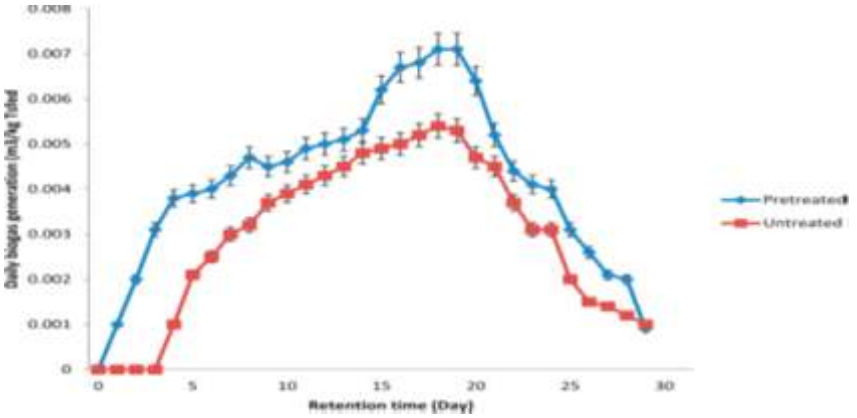

Figure 22. Daily biogas generation in the anaerobic co-digestion of the two samples of T. diversifolia shoots and poultry droppings.

The physicochemical and microbial characteristics of the substrates (*T. diversifolia*, poultry droppings, and rumen contents) were evaluated using standard methods. The initial high chemical oxygen demand (COD) values were significantly reduced by 60.45 and 56.33% after digestion. In all the experiments, biogas production was progressive until between the 16th and 21st days in most cases, after which a decrease was observed until the end of the experiments. The most desirable actual/experimental biogas yields from both experiments were 2984.20 and 1408.02 m^3/kg total solids (TS), with the desirability of 100% for both experiments. Gas chromatographic analysis revealed the CH_4 and CO_2 contents of both experiments to be 67 ± 1.5%; 22 ± 2% and 60 ± 1%; 23 ± 2%, respectively. The response surface methodology (RSM) model and the artificial neural networks (ANNs) model were employed in data optimization. In all, there was a 54.44% increase in predicted biogas yield in the experiment with pretreatment over the untreated. Based on the coefficient of determination (*R*2), the mean error, and predicted biogas yields, the ANNs model was found to be more accurate than RSM in the study. The energy balance revealed positive net energy which adequately compensated for the thermal and electrical energies used in carrying out thermo-alkaline pretreatment. The co-

digestion of these substrates for bioenergy generation is hereby advocated.

Chancellor, Sir, I can summarise to say that over 50% of food consumed in Nigeria are of satisfactory microbial load. Poor environmental sanitation and personal hygiene of food handlers are the bane of foods produced and consumed in Nigeria; education of the food handlers, regular inspection of foodservice environment and enforcement of food safety rules and regulations are required. I have tried to be focused on my chosen area of research, which is food quality and safety evaluation at the consumer level. God has also helped me to have 2 products in the market. However, my research has created several other fields of research, which are more prone to product development. To date, I have trained Ph.Ds in the following areas and they are all doing well. Dr. Ahaotu Ndidiamaka is into food fortification, she has input in most of the food fortification projects in Nigeria today. Associate Professor Kenneth Nwanelli is doing exploits in the field of dairy microbiology. The main authority in the area of food waste conversion to biofuel in Nigeria today is Professor Samuel Dahunsi, he is a product of this research effort. Mycotoxicology is a rare field because of the sophisticated instrument needed in the research, to the glory of God, Dr. Bunmi K. Olopade was trained, in this research effort, thanks to Covenant University in collaboration with the University of Johannesburg, South Africa. Dr. Ugboko Harriet is doing exploits in the field of microbiome in health and diseases. Animal feed production from agricultural waste and probiotic fortification have Elisabeth Onibokun and Onu-Okpara doing exploits in the field and with a major feed producing company; fortification of our local condiments and drinks with probiotics and functional food development has Obafemi Dorcas on board. I am fulfilled, Sir, because I have replicated myself in my field of endeavour and to God be the glory.

10. CONCLUSION

In the words of Bishop David Oyedepo "when God speaks everything (animate and inanimate) hears and line up" Microorganisms are veritable instruments in God's hand: On good authority, I can confidently tell this audience that the Bible is the best microbiology life manual ever written. Take your time and go through some of the microbial activities highlighted, Genesis 19:33;

Exodus 7:14-24; Exodus 8:20-32; Exodus 9:8-35; Exodus 12:18; Exodus 16:19; 1 Samuel 1:13; 2 Kings 5:1; 2 Kings 5:27; 2 Chronicles 26: 20-23; Mathew 8:3; Mark 1:40-42; Luke 5:13; John 2:7-10; Acts 12: 21-23, it will guide you to live a life of renunciation. You will maximize everything and never hold onto anything because they are all ephemeral. You will naturally not speak against genuine men of God because microbial-induced mouth odour (halitosis), cancer of the mouth, rhino-nose, alcoholic yeast syndrome/disease will visit you. You will naturally not be greedy over anything because foodborne diseases and bio-degradation/ deterioration of everything acquired will await you; you will naturally live a disciplined life because of known and unknown venereal diseases and all challenges of unfruitful life, curable and incurable microbial diseases await you. Get it clear that COVID-19 is not the last pandemic, less than $^{1}/_{10th}$ of the microorganisms and their activities are known to man, even the known ones are not fully understood by man with the mutations and re-emergence of strains and species. Life is not free, there is an owner, GOD; every abuse/negligence will be paid for dearly either individually or collectively.

Condemning our products in preference to imported ones is a disservice to our fatherland. A bottle of kunun-zaki, zobo, tiger nut drink, the smoothie is 100% more nutritious and microbiologically healthier than any soft drink in our market. A plate of local salad made from iru, ugba, ogiri, opehe is 100% more nutritious and microbiologically safer than any brand of salad mix/ processed foods in our markets. Can you imagine how many persons will be off unemployment market and how many multi-millionaires will emerge if we patronize our local products the way we patronize the coloured sugar water we all consume as drinks with no nutritional value and terrible health consequences. As parents, we caution our kids not to take more than a specific quantity of these drinks/processed food, by implication we are very cautious of their danger but have no courage to absolutely reject it and go for local products that we do not need any caution to take. What then is the problem? SOCIAL STATUS

Chancellor Sir, observe that some products are there in the markets from my research works. I do not emphasize patents and industrial production of our local products for some reasons. What we need as a nation now is massive education of the people and one of the ways to

achieve this is to produce a good product that will challenge what is in existence and make the knowledge free for others to emulate and do the same. Patenting conceals the know-how and makes the product expensive and breeds ground for fakes that further compound the challenges already in existence. Secondly, the local producers in the rural areas depend on the production of these products for their livelihood, in fact, most of us seated here were trained with the proceeds of this local trading. The patenting and industrial production of these local fermented foods will not benefit the local trader but further, impoverish our parents in the villages that depend on this trade. We must create a balance in all that we do with the ultimate goal of achieving effective and sustaining food safety measures via responsible consumption and production (SDG 12). Let me also report that most of our publications are normally sent to organisations, businesses, and companies whose products/samples were analysed as a way of educating them and encouraging them to improve on food safety measures.

11.0 The Way Forward/Recommendations for safe food

It is the safety of foods that guarantees a good immune system and checkmates the microbe make-up of man, to achieve this, the following are my recommendations:

1. Education of the food handlers and the public on good/standard hygiene practices, safe food handling/good manufacturing practices (GMP), HACCP/HARPC from the cradle is recommended.
2. Inspection of facilities is required to make sure that they comply with standard specifications.
3. Regular microbiological testing of food items, specifically at the consumer level is advised, to help food personnel adhere to standard specifications.
4. Standardisation of locally produced foods/drinks is advocated, with respect to:
    i. packaging
    ii. quality control
    iii. government policies on acceptance promotion and enabling environment. This will help our local food meet the international standards

12.0 Concluding Remark

We need more detailed researches on our foods to help us tell our own story. Food is the main item of trade worldwide; in the food business, nobody will promote you above their trade interest. My inauguration today into the professorial cadre is a clarion call for me to intensify research efforts in the critical areas of our foods that will present our foods in the correct perspective of safe food that will meet all food standards. To achieve this, Chancellor, I humbly request that more laboratories be established for the Department of Biological Sciences to accommodate a food lab. Deliberate effort should be made by CU to encourage our networks of primary and secondary schools to embrace practical agriculture and home economics, catching them at that stage to develop an interest in food safety issues is better than having Agric and food scientists that picked the option due to low JAMB scores.

13. ACKNOWLEDGEMENTS

Chancellor Sir, the Lord has been so good to me. He is the reason for my being alive today. He protected me from four different auto crashes that claimed lives and left me unhurt, and from the one that birthed the topic of this inaugural lecture. He protected me from three different highway robbery attacks without my losing a dime to the robbers. Growing up in Lokoja was fun and I vividly can remember when I lost two friends to the river Niger tides even when we were all swimming in the same river. To God alone be the glory.

Permit me to salute individuals whom God used to bless and lift me to this lofty height. The Chancellor of CU, Dr. David Olaniyi Oyedepo, for creating this platform that has raised and is still raising giants. Sir, you have been a blessing to me. The first time I met you in 1994, in your characteristic joke you said that this is the first time you saw a king Solomon not putting on a crown, you proclaimed your blessings, your prayer of enthronements has been fulfilled in my life. I salute and appreciate the Pro-Chancellor, Bishop David Abioye, your charge to us in one of the operation take-over evangelism outreaches in 1997 is still a driving force in my life giving me the courage to take over anything I so desire. Thanks to the Board of Regents, the University Secretary, Pastor Adedeji Owojaiye, and the Management of Covenant University for the good leadership

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Ladies and gentlemen, with these few points from my research efforts, I hope that you are all convinced and not confused that the foods consumed by Nigerians are not grossly contaminated and nutritionally unsafe, and that the microscopic invisible organisms (microorganisms) do not only rule/control man and the world, man is but packets of microorganisms on safe food with the spirit of God inside the packet elevating man to enjoy divine blessings beyond every other creature.
I thank you all for honouring me and listening.

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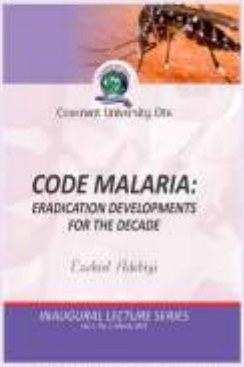
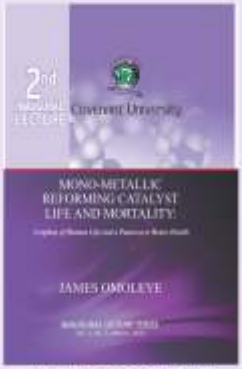
NOTE



EZEKIEL ADEBIYI



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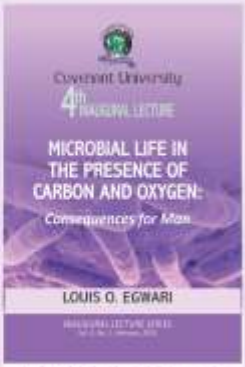

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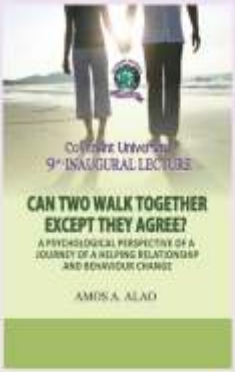
OLUFEMI J. ADEYEYE

CHARLES K. AYO

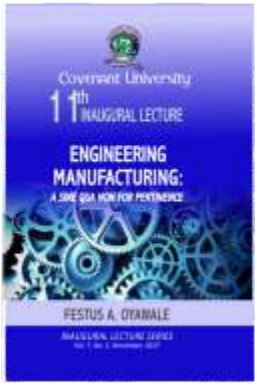
CHRISTOPHER AWONUGA



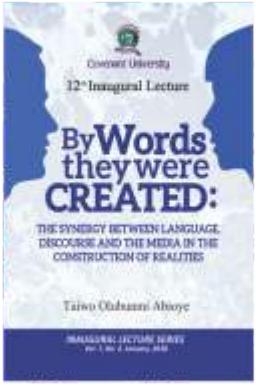
AMOS A. ALAO

COVENANT UNIVERSITY INAUGURAL LECTURE SERIES

ISAIAH OLURINOLA

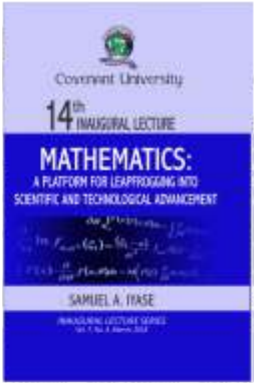


FESTUS A. OYAWALE



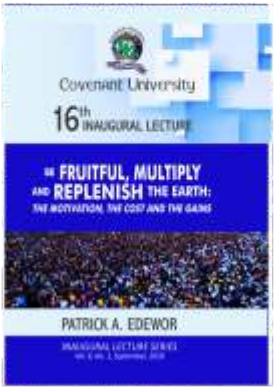
TAIWO O. ABIOYE

ABIODUN GESINDE

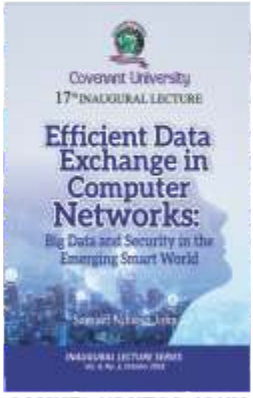


SAMUEL A. IYASE

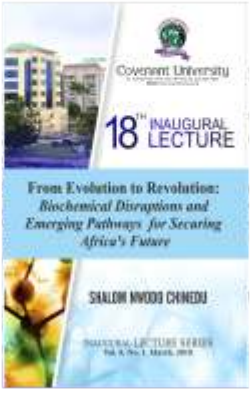
AIZE O. I. OBAYAN



PATRICK A. EDOWOR



SAMUEL NDUESO JOHN



SHALOM N. CHINEDU

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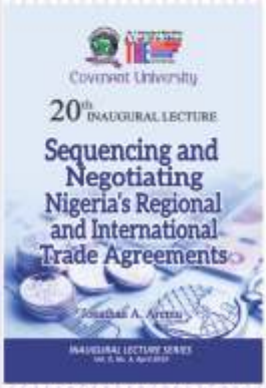
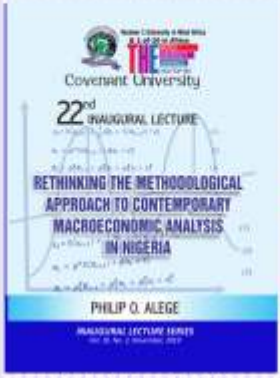
OLAWOLE O. OBEMBE

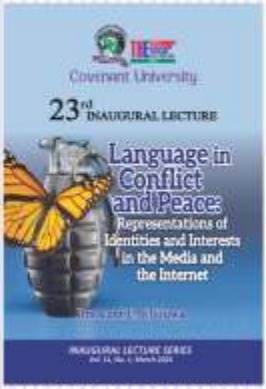


JONATHAN A. AREMU

KOLAWOLE O. AJANAKU



PHILIP O. ALEGE

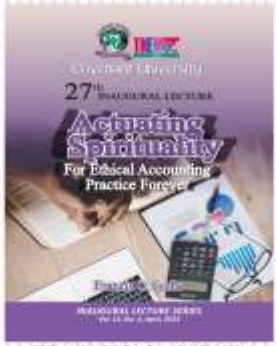


INNOCENT E. CHILUWA

OLABOSIPO I. FAGBENLE

DANIEL E. GBEREVBIE

EMEKA E. J. IWEALA



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