FEDERAL UNIVERSITY OF AGRICULTURE
ABEOKUTA NIGERIA

90th INAUGURAL LECTURE

THE SAFE JOURNEY OF FOOD FROM FARM TO FORK

by

Professor (Mrs.) Adebukunola Mobolaji Omemu

(Professor of Food Microbiology and Safety)

Department of Hospitality and Tourism
College of Food Science and Human Ecology
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of

The Vice-Chancellor

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FUNAAB INAUGURAL LECTURE SERIES

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THE SAFE JOURNEY OF FOOD FROM FARM TO FORK

PROTOCOLS

The Vice-Chancellor,

Deputy Vice-Chancellor (Academic),

Deputy Vice-Chancellor (Development),

Registrar and other Principal Officers of the University,

Deans of other Colleges and Dean, Postgraduate School,

Directors of Centers and Institutes,

Head, Department of Hospitality and Tourism,

Heads of other Departments,

Distinguished Members of the University Senate,

Distinguished Academic and Professional Colleagues in FUNAAB and from other Universities,

My Academic Mentors,

My Lord Spiritual and Temporal,

Members of my Immediate and Extended Families,

Special Guests,

Gentlemen of the Press,

Distinguished Ladies and Gentlemen,

Great FUNAABITES!

PREAMBLE

Eccl 9 verse 11: I returned and saw under the sun that the race is not to the swift, nor the battle to the strong, nor bread to the wise, nor riches to men of understanding, nor favour to men of skill, but time and chance happen to them all (NKJV).

Presenting an inaugural lecture is both a privilege and an obligation. It is a privilege because it signifies recognition of one's expertise, accomplishments, and contributions in a particular field of study, provides a platform to share knowledge, and is often a celebratory event. It is an obligation because it upholds academic traditions, encourages knowledge sharing, and serves as a form of mentorship, benefiting the academic community and future generations. Thus, I am thankful to God for granting me the grace to fulfil this obligation and also partake in this privilege.

Mr. Vice Chancellor, Sir, this inaugural lecture is the 90th in the series of FUNAAB Inaugural Lectures, the 7th from the College of Food Science and Human Ecology and the1st from the Department of Hospitality and Tourism. To God alone be the glory. Amen.

My Journey of Change: From Microbiology To Hospitality

Mr. Vice Chancellor Sir, permit me to commence this lecture by delving into the historical aspect of my career journey. Heraclitus, the Greek philosopher, aptly stated that "*change is the only constant in life*", a truth that echoes through time. Despite this, people often resist changes due to a preference for the familiar and the fear of the unknown. Our aversion to change stems from a deep-seated desire for comfort and stability. Humans are creatures of habit and we mostly find solace in routines. However, the paradox lies in the fact that it is through change that we find fertile ground for growth, resilience, and personal development. Change opens doors to new opportunities and perspectives, catalyzing transformation and renewal.

I want to echo it that change has been a constant companion in my career journey. My journey of change commenced at the Department of Biological Science, where I first cut my career teeth; to the Department of Microbiology where I sharpened my methodological skills and developed intellectual muscle; then my brief academic sojourn in the Department of Foodservice and Tourism, and finally to my current Department of Hospitality and Tourism where I attained professional maturity and became the first Professor in that Department.

I came into FUNAAB (then UNAAB) at Isale Igbehin as an M.Sc. student and after many years, I graduated in 1997 as the first M.Sc. graduate of UNAAB! Meanwhile, I already commenced my career journey as a Graduate Assistant in 1995 in the Department of Biological Sciences. I later moved to the Department of Microbiology when the Department had to stand on its own in 2005. After that, I thought I had my career journey mapped out fully in the Department of Microbiology, but life has a way of surprising us; a turning point and the need for change came again in 2012. Of course, I resisted the change, I fought tooth and nail to stay in my comfort zone. It was not an easy decision for me to take because it meant leaving a department I had spent close to twenty years and embarking on a new path that initially seemed worlds apart from my scientific roots. But after lots of consultations, consideration, and advice, I moved to the Department of Food Service and Tourism where I became the Head of Department. While still trying to find my bearing and trying to make myself relevant in the new department, the need for a change came again just a year down the line during the first accreditation exercise of the Department. This change was inevitable and resulted in the restructuring and renaming of the Department to Hospitality and Tourism.

It is important to note that all these transitions for me came with lots of questions and uncertainties. I faced the fear of leaving behind the familiar and embarking on a new path. Questions swirled in my mind: Would my background in microbiology be relevant in this new space? What would become of my career as a food microbiologist?However, despite the initial uncertainties, I embraced the challenge of adapting to a different environment, learning new skills, and understanding the intricacies of Hospitality and Tourism. Suddenly I have to take courses in event management, liquor studies, introduction to hospitality and tourism among others. Over time, I came to realize that my microbiology background, coupled with my understanding of microbial hazards and food safety protocols are valuable assets. While microbiology taught me the science behind food safety, Hospitality and Tourism taught me the art of human connection, the value of exceptional services, and the joy of creating unforgettable experiences for people.

Mr Vice Chancellor, Sir, my journey is a reminder that our lives and careers are not bound by the paths we initially set out on, instead, they are shaped by our willingness to explore, learn, adapt, and embrace changes. My journey celebrates the beauty of the unknown and the richness of diversity. In embracing change, I discovered the joy of learning, the excitement of challenging myself, and the fulfilment of contributing to an industry focused on creating unforgettable moments. Today I share my journey with the hope of inspiring others to embrace change, explore new horizons, and recognize the value of diverse perspectives in shaping the path they are passionate about.

Though I am still on the journey, but reflecting on my journey so far, I find it immensely rewarding and I give glory to God. Despite the twists and turns, I experienced many "firsts" in my journey: the first M.Sc. student from both the former College of Natural Sciences and the Department of Microbiology. When department of Foodservice and Tourism got a new name, I became the first Head of Department, Hospitality and Tourism (HTM); then the first Professor from HTM, first female Deputy Dean, Postgraduate School; first female Dean of Student Affairs and presently the first Professor from HTM to serve as Dean, College of Food Science and Human Ecology (COLFHEC). Today, I am highly honoured to stand before you as the first Professor from HTM to present an inaugural lecture. These achievements are not just mine alone but a reflection of the collective efforts and support of colleagues, mentors, and the entire FUNAAB community.

Mr. Vice Chancellor, Sir, and dear esteemed guests, throughout my journey of change, one steadfast element has remained constant: my unwavering love and passion for food safety. While pursuing my Ph.D. research at FIIRO, the vibrant and bustling streets of old Oshodi became my daily walk. The scene there was a real eye-opener. One day, I saw market women cutting carrots, cucumbers and lettuce in shockingly unsanitary conditions. They mixed them as salad and bagged them in nylon for sale. "Who would buy this?" I thought. How could anyone eat food prepared like that? But to my utter surprise, on my way back, all the vegetable salads were gone! The women were already prepping more. This was not just a one-time occurrence; it became a daily observation. My initial shock transformed into a spark of curiosity. I became more conscious of activities around food put on sale. Here on the streets are thriving food businesses, seemingly unconcerned with hygiene or safety. Questions about the safety of our food and who holds the key ignited within me. Right there, in the heart of Oshodi, my passion for food safety and the role of food handlers was born.

After thoroughly examining my research trajectory to date, I have selected a topic that resonates deeply with the core of my academic journey. With your permission, I would like to present my reflections grounded in the theories and practical knowledge of Food Microbiology and Safety, accumulated over 28 years. This inaugural lecture is titled Safe Journey of Food from Farm-to-Fork

1.0 INTRODUCTION

Food, the third most basic human necessity after air and water, is indispensable for survival and well-being. However, paramount to the enjoyment of this vital resource is the assurance of its safety. Across local and global food systems, the belief that "unsafe food is not food" highlights how contaminated food cannot provide the nutrients needed to sustain growth, health, and well-being (GAIN, 2020a).

In 1983, FAO/WHO experts highlighted contaminated food as a major health issue impacting economic productivity. In 1992, the International Conference on Nutrition emphasized the role of contaminated food and water in communicable diseases, affirming that access to safe food is a fundamental right. Also, at the 2012 Conference on Sustainable Development (Rio+20), world leaders reaffirmed the right of everyone to access safe and nutritious food, consistent with the right to adequate food and the fundamental right of everyone to be free from hunger (United Nations, 2012). According to the report of the Global Alliance for Improved Nutrition, progress toward achieving the UN's second Sustainable Development Goal (SDG 2) – "end hunger, achieve food security and improved nutrition, and promote sustainable agriculture" by 2030 may be jeopardized if safety is not ensured throughout the journey of food from farm to fork (GAIN, 2020b). Threats to food safety can occur at any stage of the value chain from production to consumption and can range from contamination with pathogens or toxins to the use of unsafe additives as well as unsafe handling or storage that aggravates the risk.

Unsafe food results in over 200 diseases, from diarrhoea to cancer. It also creates a vicious cycle of disease and malnutrition, particularly affecting vulnerable populations like infants, young children, the elderly, and the sick. According to World Health Organization's report, an estimated 600 million people, almost 1 in 10 people globally fall ill after eating contaminated food, leading to

420,000 deaths and a loss of 33 million healthy life years (DALYs) every year. Children under five are especially vulnerable, with around 125,000 deaths annually in this age group alone. Notably, about 75% of these deaths occur in South Asia, Southeast Asia, and parts of sub-Saharan Africa. In Africa specifically, the WHO African Region estimates approximately 91 million illnesses and nearly 137,000 deaths each year due to consumption of contaminated food (WHO, 2015).
The economic impact of unsafe food is just as alarming. A World Bank (2018) study found that unsafe food costs low-and middle-income countries $110 billion annually in lost productivity and medical expenses. This figure excludes the additional costs of rejected food exports and potential market share losses.

Each year in Nigeria, over 200,000 individuals lose their lives to food poisoning, resulting from contamination due to inadequate farming, processing, preservation, and product adulteration. The financial burden of foodborne illnesses on the Nigerian government is estimated at US$3.6 billion annually (Ezirigwe, 2018)

Globally, the burden of unsafe food is expected to rise significantly in the coming years if no corrective actions are taken. However, the Safe Food Imperative advocated that much of the burden of unsafe food can be avoided through preventive measures, investments, and behavioural changes adopted from farm-to-fork (Jaffee *et al.,* 2019). The current system for monitoring food safety is fragmented, with responsibility shared by multiple stakeholders rather than centralized under a single regulatory body. This makes ensuring food safety throughout a globalized supply chain increasingly difficult. A single weak link can compromise the entire chain, hence the critical need to strengthen every step of the process.

1.1 The Journey of Food From Farm To Fork

The "farm to fork" journey also known as the food supply chain is the processes that describe how food moves from production on farms to consumption by individuals (Figure 1). In the modern world, the journey of food from its origin on the farm to its consumption at the dinner table is a marvel of complexity. It could be a short hop from a nearby farm stand, or a globe-trotting adventure spanning continents. The distance food travels from the location where it is grown to the location where it is consumed has been increasing steadily over the last 50 years. Studies estimate that processed food in the United States travels over 1,300 miles, and fresh produce travels over 1,500 miles, before being consumed (Schnell, 2013). Depending on the location, type of food, and distribution network, the distance food travels varies widely, and this has implications for freshness and safety.

The food journey from farm to fork involves a series of interconnected stages namely production, harvesting, processing, packaging, distribution, and finally, consumer preparation and consumption. At the heart of this journey lies a dynamic interplay between microorganisms, and humans. Any compromise of safety by any of these actors (microorganisms and humans) along the journey from farm to fork can pose untold risks to food safety.Understanding the roles of these diverse actors and the challenges they face is crucial for ensuring the safe arrival of food on our plates.

My inaugural lecture will focus on the role of humans and microorganisms as actors in the safe journey of food from farm-to-fork

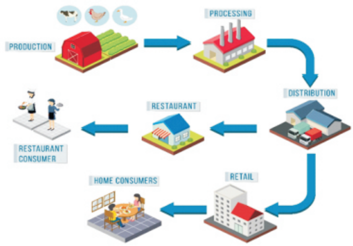

Plate 1: The Food Supply Chain
Source: https://www.freepik.com

1.2 Microbial and Human Contributions in the Safe Journey of Food From Farm-To-Fork

1.2.1 Microbial contributions

Microbial contributions in the safe journey of food from farm to fork refer to microorganisms' roles in various stages of the food supply chain, influencing its safety, quality, and preservation. These contributions include both beneficial and detrimental aspects. Beneficial microorganisms such as lactic acid bacteria aid in fermentation, preservation, and biological control, enhancing food safety and quality. On the other hand, detrimental microorganisms can cause food spoilage while contamination with pathogenic microorganisms can lead to food-borne illnesses thus posing risks to public health (Buzby, *et al.,* 2014; Zanin *et al*., 2017).

1.2.2 Human contributions

Human contributions in the journey of food from farm to farm refer to the actions, practices, and efforts of individuals involved in various stages of the food supply chain. These contributions, which can be beneficial or detrimental, play a critical role in ensuring the safety, quality, and availability of food for consumers. Through responsible agricultural practices, adherence to food safety standards, and education initiatives, individuals contribute to safeguarding the integrity of the food supply chain. However, actions such as misuse of pesticides, fertilizers, and antibiotics, food fraud and adulteration, supply chain disruptions, and exploitative labour practices can compromise the safe arrival of food on our plates (Schnell, 2013).

1.2.3 Importance of ensuring safety throughout the journey of food from farm-to-fork

Ensuring safety throughout the journey of food from farm to farm is essential for multiple reasons. Contaminated food can lead to illness, so strong safety measures throughout the supply chain protect public health. Also, when individuals trust that the food they consume is safe, they are more likely to make purchases and support the food industry. This consumer confidence is foundational for the industry's reputation and sustainability.

Furthermore, safety lapses are costly. Recalls, lawsuits and damaged reputations can financially cripple businesses across the food supply chain. By prioritizing safety, companies mitigate these risks and operate more securely. Additionally, compliance with regulations is essential. Governments impose standards to guarantee food safety at every stage of the food chain. Adhering to these regulations is crucial for businesses to operate legally and responsibly.

Additionally, in today's globalized world, safety standards are essential for international trade. Countries often have specific requirements for imported food products, and failure to meet these standards can lead to trade barriers or bans, limiting market access and profitability. Finally, sustainable food safety practices are crucial for the future. Preventing contamination and waste ensures a safe and nutritious food supply for generations to come.
(Fung *et al*., 2018; FDA, 2021).

1.3 Food Safety

Seward (2003) explains that the concept of "safe food" varies among different groups, such as consumers, academicians, and industry. FAO/WHO (1997) defined food safety as the assurance that food will not cause harm to the consumer when it is prepared or eaten according to its intended use. It involves measures to prevent contamination, minimize the risk of foodborne illnesses, and ensure that food products meet quality and hygiene standards. This includes various steps such as proper handling, storage, preparation, cooking, and serving of food to prevent the growth of harmful bacteria, viruses, parasites, toxins, or chemicals that could pose health risks to consumers. Food safety also encompasses regulatory standards and guidelines established by authorities to regulate food from production to consumption.

Food safety is a very critical aspect of daily life that often goes unnoticed until a crisis occurs.In the year 2000, the World Health Assembly unanimously recognized food safety as a critical public health concern. This recognition underlines its vital role in safeguarding the health of everyone on the planet. Further emphasizing this importance, the United Nations declared June 7th as World Food Safety Day. This annual event serves as a global reminder of the paramount importance of safe food handling. It highlights the need for safe practices throughout the entire food journey, from farm to fork, to protect everyone's health.The theme for World Food Safety Day 2024 is *Food Safety: Prepare For The Unexpected.*

Adherence to safe food practices enhances individual health and also contributes to the overall health of communities and populations. Moreover, regions and communities that prioritize food safety often experience enhanced economic growth and stability (Fung, 2018; WHO, 2020). However, with the complexity of modern food production, which includes diverse ingredients and global distribution networks, guaranteeing food safety remains both a complex challenge and an indispensable necessity (Batt, 2016).

1.3.1 Who ensures food safety?

As the theme of World Food Safety Day in 2000 goes, "Food safety is everyone's business". The safety of our food supply is a result of collaborative efforts involving government agencies, international organizations, the food industry, processors and consumers. Government agencies like the Food and Drug Administration (FDA) and the United States Department of Agriculture (USDA) set and enforce food safety regulations, while international organizations like the World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) establish global standards. Food producers and retailers implement quality control measures, and consumers play a role by following proper food handling practices. This collective approach helps to minimize the risk of foodborne illnesses and ensures the safety of the food from the farm to the table.

In Nigeria, multiple government bodies play a role in ensuring the safety of foods along the farm to table continuum. The National Agency for Food and Drug Administration and Control (NAFDAC) is the primary regulatory body that sets standards, inspects facilities, and enforces regulations. Other key players include the Federal Ministry of Agriculture and Rural Development (FMARD), the National Agricultural Quarantine Service (NAQS), state health and agricultural ministries, and the Standards Organization of Nigeria (SON) (Okoruwa and Onuigbo-Chatta, 2021).

1.3.2 Food safety hazard

A food safety hazard is any factor present in food that has the potential to cause harm to the consumer, either by causing illness or injury (Lawley *et al*., 2012). Food safety hazards throughout the farm-to-fork journey can cause foodborne illnesses, ranging from mild to life-threatening, especially for vulnerable groups like children, pregnant women, and the elderly. These hazrads can be naturally present in food or introduced during production, processing, storage or transportation. They are typically categorized into three main types: biological, chemical and physical hazards.

Biological hazards are microorganisms like bacteria, viruses, parasites, and fungi. and biological toxins that can contaminate food and cause illness in consumers. They are the main cause of acute foodborne illness in humans and Common examples of biological hazards in food include bacteria (e.g., *Salmonella, E. coli, Listeria monocytogenes*), viruses (e.g., Norovirus, Hepatitis A), parasites (e.g., *Cryptosporidium, Trichinella*), fungi (e.g., *Aspergillus, Penicillium*), and toxins (e.g., botulinum toxin, mycotoxins) (Table 1).

Table 1: Biological Hazards and Common Sources of Contamination from farm-to-fork

Biological Hazard	Common Sources of Contamination
Bacteria	- *Salmonella*: Raw poultry, eggs, unpasteurized dairy products. - *E. coli*: raw produce, contaminated water. - *Listeria monocytogenes*: soft cheeses, smoked seafood.
Viruses	- *Norovirus*: Contaminated water, shellfish, salads. - Hepatitis A: Contaminated water, shellfish, fruits, vegetables.
Parasites	- *Toxoplasma gondii*: Undercooked/raw meat, soil, water. - *Cryptosporidium*: Contaminated water, irrigation, washing.
Molds and Fungi	- *Aspergillus spp*.: Grains, nuts, dried fruits in poor storage. - Mycotoxins: especially grains, nuts, coffee beans.
Microbial Toxins	- Produced by certain bacteria and moulds under specific conditions.

Source: FDA, 2020; CDC, 2020

Chemical hazards are those that can contaminate food and pose a risk to human health when consumed. These hazards can occur naturally or be added during food processing, either intentionally or unintentionally. Intentionally added chemicals like additives, pesticides, veterinary drugs, and adulterants are safe within established levels, however, exceeding these established levels can pose dangers. Unintentional chemical agents include sanitizers, environmental chemicals, and naturally existing toxins (Table 2). Adherence to approved chemical usage ensures that Maximum Residue Limits (MRLs) are not surpassed in food cultivation or manufacturing.

Physical hazards are foreign objects or extraneous materials that can accidentally contaminate food products and pose risks such as choking, internal injuries or broken teeth to consumers. Typical examples include glass, wood, metal, bone, plastic, stones, and insects.
By understanding these hazards and taking steps to prevent them, safe food can be delivered to consumers.

Table 2: Chemical Hazards and Sources of Contamination in the Food Chain

Chemical Hazard	Common Sources of Contamination
Pesticides	- Agricultural use on crops, fruits, - Residues on food from improper application or persistence.
Heavy Metals	- Environmental pollution from industrial activities. - Contaminated soil, water, and air
Food Additives	- Intentional use in food processing for preservation, color, - Improper use or excessive levels in processed foods.
Veterinary Drugs	- Residues in animal products (meat, milk, eggs) from veterinary treatments. - Improper withdrawal periods before slaughter.
Industrial Chemicals	- Contamination from processes or packaging materials. - Migration of chemicals from packaging into food products.
Environmental Contaminants	- Persistent organic pollutants (POPs) in soil, water, and air.
Allergens	- in food ingredients such as nuts, milk, soy, wheat, - Cross-contact during processing or handling
Natural Toxins	- Occur naturally in certain plants, fungi, or seafood.

Source: FAO, 2023

1.3.3 Food safety and the sustainable development goals.

Food safety plays a critical role in achieving several of the Sustainable Development Goals (SDGs) set by the United Nations. Food safety combats hunger by minimizing waste and ensuring access to healthy food (Goal 2: Zero hunger). It promotes good health by reducing foodborne illnesses (Goal 3: Good Health and Well-being). Goal 12 (Responsible Consumption and Production) is encouraged by food safety practices that minimize contamination. Strong food safety standards (Goal 8: Decent Work and Economic Growth) boost trade and economic growth. Overall, safe food from farm to fork supports a world with sufficient, nutritious, and safe food for all, which is a cornerstone of achieving the SDGs.

1.4 Microorganisms

Microorganisms, often referred to as microbes, are microscopic living organisms that are too small to be seen with the naked eye. Microorganisms may exist in a single-celled form or as a colony of cells. They include bacteria, viruses, fungi, protozoa, and algae. Despite their small size, they play a significant role in ensuring the safe journey of food from farm to fork with both positive and negative impacts.

1.4.1 Beneficial contributions of microorganisms to food safety.

Microorganisms play several beneficial roles in ensuring food safety through fermentation, probiotics, biological control, food preservation, and bioremediation.

Fermentation, involves the transformation of food by microorganisms, resulting in distinctive flavors, textures, and increased nutritional value. Traditionally, fermentation occurs through a spontaneous process utilizing microorganisms present in the environment, raw ingredients, or utensils. This ancient technique is typically practiced in home-based or local food production settings, with methods passed down from generation to generation. Modern approaches however make use of starter cultures to ensure consistent and safe products (Campbell-Platt, 1987; Skowron *et al.,* 2022).

In Africa, diverse fermented foods exist, categorized by their primary raw materials: tubers (*Fufu, Gari*), cereals (*Ogi, Kunnu, Pito*), legumes (*Iru, Ogiri*), and dairy (*Wara,Nunu*) (Table 3). The microorganisms involved in these fermentations primarily include lactic acid bacteria (LAB), bacilli, other Gram-positive and a few Gram-negative bacteria, yeasts, and filamentous moulds, often originating from ingredients, utensils, or the environment and selected for their substrate adaptation (Tamang, 2020).
During fermentation, the dominant fermenting microorganisms, along with their metabolic byproducts and pH alterations, suppress the growth of pathogenic microorganisms, enhance nutrient bioavailability, preserve food through acidity, and generate probiotics, supporting gut health and digestion.

Table 3: Common fermented food/beverages and the microorganisms implicated

Fermented product	Raw substrates	Some microorganisms implicated
Ogi	Maize, sorghum, millet	*Lactobacillus plantarum* *S. cerevisiae, Candida krusei*,
Iru	African locust bean	*Bacillus*, *Staphylococcus* spp.
Gari	Cassava	*Lactobacillus plantarum* *Bacillus subtilis*, *Candida krusei*
Mahewu	Maize or sorghum	*Lactobacillus bulgaricus*, *L. brevis*
Marula	Amarula fruit	Yeasts
Bushera	Sorghum or millet	*Lactobacillus* spp., *Streptococcus* spp., *Leuconostoc* spp.
Chibuku	Sorghum	*Lactobacillus* spp., *Saccharomyces cerevisiae*
Umqombothi	Maize or sorghum	*Lactobacillus* spp., *S. cerevisiae*
Ogiri	melon seeds	*Bacillus subtilis*, other bacterial species

Source: Mokoena *et al.,* 2016

Probiotics are live microorganisms that, when consumed in sufficient quantities, provide health benefits to the host (Hill *et al.,* 2014). Found naturally in traditional fermented foods like yoghurt and kefir, they must meet specific criteria to be classified as probiotics. These include proper identification, safety for both food and clinical applications, survival through the digestive tract, adherence to mucosal surfaces, colonization of the intestines, production of antimicrobial substances, documented health effects, and stability during processing and storage. Common microorganisms used as probiotics are *Lactobacillus, Bifidobacterium*, and certain nonpathogenic strains of *Escherichia coli*, with research suggesting potential in other lactic acid bacteria as well (Kunes and Kvetina, 2015).

Probiotics offer a variety of health advantages, such as the prevention of various digestive disorders, including antibiotic-associated diarrhoea and irritable bowel syndrome. Some studies indicate a positive effect of probiotics on cholesterol, blood pressure, and even some cancers (Doron and Snydman, 2015).

1.4.2 Detrimental contributions of microorganisms to food safety

Microorganisms pose threats to food safety through microbial spoilage and foodborne illness.

Microbial food spoilage is the deterioration of food quality by the activity of microorganisms such as bacteria, moulds, and yeasts. These microorganisms can multiply and produce enzymes that break down food components, leading to unpleasant changes in taste, texture, odour, and appearance. Common signs of microbial food spoilage include off-odours, slime formation, discolouration, and gas production. Microbial food spoilage is a food safety concern because it can create an environment for harmful microorganisms to grow, potentially leading to foodborne illness. Spoiled food might also contain toxins produced by the spoilage microbes thus posing a further health risk (Ray, 2005). Foods are susceptible to spoilage and contamination of pathogenic microorganisms throughout the food chain, retail shops, restaurants, and houses of consumers (Aung and Chang, 2014). Spoilage microbes are often common inhabitants of soil, water, or the intestinal tracts of animals and may be dispersed through the air and water and by the activities of small animals and humans.

Common spoilage organisms proliferate in food products under conditions of improper storage, temperature abuse, or inadequate packaging and they include bacteria, moulds, and yeasts (Table 4).

Table 4: Common Food Spoilage Microorganisms

Microorganism	**Common Food Sources**
Bacteria	
Pseudomonas spp.	Dairy products, meats, vegetables
Bacillus spp.	Canned foods, dairy products
Lactobacillus spp.	Dairy products, pickled vegetables
Leuconostoc spp.	Fermented vegetables, dairy products
Staphylococcus spp.	Meat, poultry, dairy products
Escherichia coli	Raw or undercooked meats, raw vegetables
Yeasts	
Saccharomyces spp.	Fruit juices, syrups
Debaryomyces spp.	Dairy products, fruit juices
Molds	
Aspergillus spp.	Nuts, grains, dried fruits
Rhizopus spp.	Fruits, vegetables, bread
Mucor spp.	Fruits, bread, cheese

Source: Lorenzo *et al.,* 2018

Foodborne illness, also known as food poisoning, refers to the illness or disease caused by consuming contaminated food or beverages (WHO, 2020). These contaminants can include harmful bacteria, viruses, parasites, or toxins that can make people sick when ingested. Foodborne illness encompass a wide range of illnesses, from mild gastrointestinal discomfort to severe conditions like cancers. Symptoms include nausea, vomiting, diarrhoea, abdominal pain, fever, and fatigue, which can lead to dehydration, organ damage, and death, especially in vulnerable populations such as young children, the elderly, pregnant women, and those with weakened immune systems.

Foodborne illness can manifest in three main forms: foodborne infection (caused by ingesting live pathogens like *Salmonella*, leading to delayed symptoms), foodborne intoxication (Caused by consuming pre-formed toxins in food, often from *Staphylococcus*

aureus, resulting in rapid symptoms) and Toxico-infection (A combination of both, like *E. coli* O157:H7, causing Shiga toxin-producing E. coli infection (Erickson *et al.,*2019).
Common practices that create opportunities for food contamination include mishandling food, inadequate cooking or refrigeration, cross-contamination, and consuming contaminated water or produce.Despite preventive efforts, foodborne illness remains a significant global health concern, aggravated by modern intensive farming, importation of contaminated food, unsafe agricultural practices, and antibiotic resistance.

1.5 Vulnerabilities Along the Farm-To-Fork Journey and Role of Humans in Ensuring Safety

Despite significant advancements in food safety, foodborne illness remains a global threat. While previous research has predominantly focused on identifying hazards, a new focus is emerging which is the human role in food safety from farm-to-fork. This includes individual knowledge, skills, and behaviours along the entire food journey. It also encompasses organizational factors like communication and workplace culture impacting food safety practices. The contribution of humans in the journey of food from farm-to-forkcan be both beneficial or detrimental

1.5.1 Human actors and vulnerabilities from farm to fork

The journey of food from farm to fork, involves many human actors (farmers, processors, distributors, retailers and food handlers, consumers and regulators) who play crucial roles but also face various vulnerabilities that can impact food safety.

Farmers' practices directly affect food quality; vulnerabilities that can compromise food safety and introduce pathogens or harmful substances into produce, include improper pesticide use, contaminated water sources, and poor hygiene (Olsen *et al.,* 2020).

The processors' role is to transform raw materials into other products and eliminate or control foodborne threats during processing. Challenges include cross-contamination, inadequate hygiene, and temperature control. In addition, reluctance to innovate or reform practices, coupled with ageing facilities and poorly designed equipment, further hinder processors' ability to ensure food safety (Sofos, 2014).

Retailers and food handlers handle, prepare, and serve food to consumers. Common issues involve unsafe handling practices, inadequate infrastructure, and high staff turnover, making training a constant struggle. In developing countries, street vendors often lack access to basic sanitation facilities (Hopkins and Beck, 2012; Fong *et al*., 2018).

Consumers represent the final link in the food safety chain, yet face their own set of challenges. Concerns at the consumer level include contamination originating from consumers themselves, primarily a lack of basic food safety knowledge and practices such as cross-contamination, improper hand washing, improper storage, and consuming expired or spoiled food. Poor temperature control in refrigerators at home can accelerate food spoilage and pathogen growth further complicating food safety at the consumer level (Lando *et al.,* 2019).

Regulatory agencies and authorities play a critical role in addressing these vulnerabilities and ensuring the safety and integrity of the food supply. These bodies set food safety standards and enforce them through inspections, audits, and monitoring.

1.5.2 Contributions of humans to ensure safety

Despite the vulnerabilities, humans contribute significantly to improving food safety through various means:

I. Good Agricultural Practices (GAP): Farmers minimize microbial contamination in fresh produce by practicing proper sanitation, water management, pest control, and safe use of agrochemicals.

ii. Good Manufacturing Practices (GMP): Food manufacturers maintain hygienic conditions in processing facilities through sanitation procedures, personnel hygiene, facility design, equipment maintenance, and raw material handling.

iii. Hazard Analysis and Critical Control Points (HACCP): This systematic approach identifies, monitors, and manages potential hazards in the food production process, ensuring safety at critical stages.

iv. Food Safety Training and Education: Food handlers receive training on proper food handling, sanitation, hygiene, and regulations to prevent contamination and foodborne illnesses.

v. Monitoring and Enforcement of Regulations: Regulatory agencies establish and enforce food safety standards, conduct inspections, and ensure compliance to protect consumers.

vi. Monitoring and Traceability Systems: Tracking food products throughout the supply chain helps promptly identify and address safety issues, reducing the risk of foodborne illness outbreaks and facilitating recalls.

vii. Consumer Awareness and Practices: Educating consumers about safe food handling practices, such as handwashing, food separation, proper storage, and cooking temperatures, helps prevent foodborne illnesses and ensures safety at home.

1.6 The Informal Food Sector and Food Safety

The informal food sector encompasses various food-related activities and businesses that operate outside formal regulations, prevalent in both developed and developing countries. These establishments are predominantly situated in low-income urban areas and along busy commuter routes, serving as vital food sources for urban residents. Characteristics of this sector include a lack of basic infrastructure and minimal capital investment. Typically, family-run, these businesses often operate from stalls, carts, or homes, utilizing traditional preparation methods that may not align with modern food safety standards and require minimal education to start. Examples of informal food businesses include street food vendors, home-based food producers, mobile food trucks, farmers' market vendors, hawkers, and neighbourhood grocery stores (Argenti *et al.,* 2003).

Recent estimates suggest the informal food sector, including street food vending and traditional or open-air markets serves between 65% and 95% of the domestic market demand for food in Low and middle-income countries (LMICs). In Nigeria, informal food vending enterprises selling street foods are located throughout the urban landscape but are particularly concentrated in low-income neighbourhoods and can be found near busy places such as transportation hubs, office blocks, and school districts (Nickanor, 2019; Adeosun, 2023 and Henson, 2023).

Despite their vital role in ensuring food security, the informal sector faces several challenges. Unregulated operations, dirty environments, lack of essential amenities like potable water, waste disposal, and limited storage facilities increase contamination and raise food safety concerns. Additionally, their activities contribute to traffic congestion and environmental pollution, prompting authorities to view them as indicators of inadequate urban development. In addition, a large part of the public health burden of foodborne disease is associated with foods that are handled and sold by informal food processors and vendors (Henson *et al.,* 2023).

Traditional efforts in most African cities to enforce food safety in this sector have focused on reactive measures which involve fines, arrests, evictions, merchandise confiscation, and market stall demolitions (Steel *et al.* 2014; Mitullah, 2003). However, such enforcement campaigns have proven ineffective and despite all the state oppression, the informal food business sector has continued to flourish. The convenience of purchasing food from them is appreciated by many consumers, including the urban poor, office workers, and tourists. Thus, this sector is unlikely to disappear.

Recently, a new approach of supporting rather than opposing the informal food sector is emerging. Some governments are now working with vendors to improve hygiene practices and working conditions. This not only benefits public health but also empowers vendors and creates a more vibrant city atmosphere. Organizations like the FAO are supporting this shift by training vendors and promoting their participation in policy discussions. This cooperative approach holds promise for a safer and more sustainable food system (Tinker, 2003; Yasmeen, 2001).

1.7 Food Safety in Nigeria

Despite numerous efforts to tackle food safety in Nigeria, the problem remains significant. Limited reporting and analysis make it difficult to accurately assess the true impact of foodborne illnesses. Though underreported, data suggests foodborne illnesses claim over 200,000 lives annually in Nigeria, costing the government an estimated US$3.6 billion (Odeyemi, 2016). Further highlighting the issue, the Consumer Advocacy for Food Safety and Nutrition Initiative (CAFSANI), reported that unsafe food results in an estimated 173 million cases of diarrhoea, and approximately 33,000 deaths from diarrhoea alone in Nigeria (GAIN, 2021). Unfortunately, a lack of seriousness about food safety appears to permeate all levels, from policymakers to consumers.

In recent years, Nigeria has witnessed a concerning rise in food safety issues. Unhygienic environments, infectious agents, and toxic substances within the food chain system are contributing factors to these incidents, tragically leading to numerous deaths. Notably, evidence points towards unsafe practices employed by food producers, manufacturers, processors, caterers, and handlers throughout the entire food chain as a key link to this surge in foodborne illnesses (Ezirigwe, 2018).

For instance, Ibiam, *et al.* (2015) reported that in Abakaliki, as in most other parts of Nigeria, it is a common practice among commercial sellers of boiled eggs to boil them with chemicals and detergents such as omo, klin, and alum. This gives the egg an ashy appearance after cooking and makes them easy to peel however there are obvious safety concerns with this practice. The use of detergent, soap, and bleach to clean fruits, vegetables, tiger nuts and some agricultural produce is a common practice, especially among retailers. However, this is a cause for concern. The outer layers (skins or peels) of fruits, vegetables, root tubers, and nuts are porous. This means they can easily absorb the harsh chemicals used for washing and constitute health issues when coonsumed.

Also, the use of unapproved chemicals like sniper is a common practice used to preserve grains like rice, maize, beans, and dried yam chips (*gbodo*). These chemicals potentially contaminate these food products and make them unsafe for consumers.

The use of nylon bags to cook or serve hot food is also a common practice that is proven to be unsafe. Cooking food directly in nylon bags or some plastic containers can potentially leach harmful chemicals into the food, especially at high temperatures. Chemicals like dioxins and BPA have been linked to health concerns. While some newer plastics are designed for hot food use, it is generally recommended to use food-grade containers labelled safe for hot foods or choose alternative materials like glass or stainless steel. Leaves can also be a safe option for certain cooking methods.

The most widely reported adulterant of palm oil are Sudan III and IV azo dyes, which are being added to palm oil to improve the colour and make it more appealing to consumers but poses health risks (Kola-Ajibade *et al.* 2021). Addition of these dyes (Sudan I, II,

III, IV) into foodstuffs contravenes EU and USA legislation and is currently banned in almost all countries due to the induction of some types of cancer related to bladder and liver in animals.
There have also been allegations of the use of calcium carbide, balms, and other insecticides by fruit sellers in Nigeria to quicken the ripening of some fruits and vegetables like banana. Plantain and mangoes. These chemicals force unnatural ripening and may leave harmful residues in the fruits.

Other reported harmful practices include tenderizing meat with paracetamol (leading to organ failure) the use of formaldehyde to preserve fish to keep fish looking fresh for longer, injecting poultry with hormones, using harmful food coloring, and many more (Ewurabena, 2022),

1.7.1 Reported food-related illnesses and deaths in Nigeria.
Although cases of food-related illnesses are grossly underreported in Nigeria, yet several high-profile incidents illustrate the gravity of food safety concerns in Nigeria. In 2008, in Bekwara, Cross River State, 112 people were hospitalized, and two children died after consuming contaminated *moi-moi* and beans. A laboratory report from the National Agency for Food and Drug Administration and Control (NAFDAC) revealed that the beans contained very high concentrations of highly toxic pesticides. In a different report, but similar outcome, over 120 students of Government Girls Secondary School, Doma, Gombe State were hospitalized after consuming beans containing very high levels of lindane (an organochlorinated pesticide commonly called Gammallin), which may have been used to preserve the beans from ants and pest attacks (Onyeaka *et al.,* 2021).

On June 4th, 2012 in Kafur, Kastina State, 26 people, including 20 children and six adults, suffered severe gastroenteritis after consuming locally made tuwo with treated guinea corn. Unfortunately, this treated guinea corn was meant for planting and

not for human consumption. Imo State. In 2015, there was a report of food poisoning caused by toxic metals in Zamfara State which resulted in the death of numerous infants and children
From July to August 2017 in Okoloke village, Kogi State, an outbreak of diarrheal illness caused by zoonotic bacteria in meat and water resulted in 62 deaths. This outbreak, initially called a "strange disease," was eventually traced back to a lack of food safety controls.

In November 2020, around 20 people were treated for acute gastroenteritis after consuming kunu produced from grains looted from a COVID-19 palliative storage unit in Joi village, Plateau State. This incident highlights the potential for contaminated food to spread illness, especially during emergencies. In April 2021, ten people died and 400 were hospitalized in Kano after consuming fruit juice that had expired over a year. This scenario highlights the poor culture of checking food expiration dates. Similarly, in March 2021, 25 people died after eating fried meat served at a bar in Alagbole-Akute, Ogun State. Surprisingly, without investigations, the deaths were classified as ritual killings instead of food poisoning issues, thus highlighting inadequate monitoring systems (Ezirigwe, 2018; Onyeaka *et al.,* 2021).

In Kano State, there was a case of food poisoning among three families due to the consumption of meal (*amala*) from yam flour (*elubo*). Investigations revealed that the use of certain lethal preservatives for the processing of the yam flour might be responsible. Another food poisoning report attributed to yam flour consumption in five families in Ilorin, Kwara State of Nigeria was also reported (Onyeaka *et al.,* 2021).

These high-profile food safety issues indicate that the unhygienic and unsafe handling and treatment of food has seriously impacted public health in Nigeria by causing numerous chronic and non-chronic diseases. Disturbingly, the root causes of these outbreaks are often not fully investigated or communicated to the public. This lack of transparency exposes gaps in Nigeria's food safety regulations and enforcement.

1.8 Emerging Challenges in the Safe Journey of Food

While significant advancements have been made in food safety, new challenges constantly emerge, threatening the safety of the food supply chain. For instance, Climate change disrupts agricultural practices, increasing crop contamination and impacting storage conditions. In addition, the overuse of antibiotics in agriculture contributes to the rise of antibiotic-resistant bacteria thus making it harder to treat foodborne illnesses caused by these bacteria.

With the globalization of food supply chains, food travels longer distances and passes through more hands before reaching consumers. This increases the risk of contamination, as well as the difficulty of traceability in case of a foodborne illness outbreak.

The rise of online grocery shopping, while convenient, introduces new challenges like temperature control during delivery or storage in consumers' homes. Another challenge which poses a significant threat to food safety is the rising case of food fraud, where products are intentionally mislabeled or adulterated for economic gain. These fraudulent practices compromise the integrity of the food supply chain and can lead to health risks for consumers. Lastly, the increasing prevalence of food allergies and sensitivities is a growing concern, and effective management of allergens throughout the food supply chain is essential.

These challenges necessitate ongoing vigilance and adaptation to safeguard the safety of our food. Addressing these emerging challenges requires collaboration among stakeholders and proactive risk assessment, regulation, and education efforts.

2.0. MY RESEARCH FOCUS AND CONTRIBUTIONS TO KNOWLEDGE.

My research activities investigated the following aspects of food safety namely:

i. The microbiology and safety of indigenous fermented foods
ii. Safety on the farm
iii. Safety of food on the streets and retail stores
iv. The role of food handlers in food safety
v. Food safety protocols: Hazard Analysis and Critical Control Points (HACCP)

2.1 Microbiology and Safety of Selected Traditional Fermented Foods

Fermented foods harbour a diverse microbial community that interacts in intricate ways. Though their presence in food may be minimal, microbes profoundly influence the quality and safety of the food. Some microorganisms are killed or inactivated during the fermentation process thus making way for strains better suited to the process. Certain microbial byproducts serve as biomarkers to assess fermentation quality and safety. Research on bacteria, yeasts, and moulds involved in fermentation aids in identifying such biomarkers and developing optimal starter cultures for improved food quality. My research focussed on the microbial dynamics and safety of some traditional fermented foods such as *ogi, lafun, elubo, iru* and *ogiri*.

2.1.1 My research on 'ogi'

Ogi, also called pap or akamu, is a fermented cereal gruel commonly consumed in West Africa. It is made through a traditional fermentation process involving two main stages: steeping and souring. During steeping, grains like maize, sorghum, or millet will be washed, soaked in water for 24–72 hours, wet-milled, and wet-sieved. The resulting wet ogi has a smooth texture, sour flavor, and distinctive aroma that differentiate it from starch and flour. The wet ogi is either cooked into a thin porridge (pap), or a thick porridge (eko or agidi). Cooked ogi is widely consumed as a weaning food for infants, soft meals for convalescents and the elderly, and as a stimulant for milk production in nursing mothers across West Africa. In some communities, uncooked ogi diluted with water is given to people with diarrhoea to reduce stool frequency. Since ogi is a staple for high-risk groups like infants, the elderly, and the immune-compromised, understanding its fermentation and storage methods is crucial for improving production and safety(Odunfa and Adeyele, 1985; Teniola and Odunfa, 2001).

2.1.1.1 Microbial succession, storage, and usage pattern of 'ogi'.
Omemu (2011) studied the fermentation dynamics, and physico-chemical changes during fermentation of *ogi* to provide a rational basis for the improvement of the processing techniques. Aerobic plate count, Lactic acid bacteria (LAB), yeasts and molds count, pH, Total Titrable acidity, and total reducing sugars during the *ogi* fermentation process were determined.

The pH decreased significantly ($p<0.05$) throughout the steeping and souring stage from 6.1 log10 cfu/g to 4.1 log10 cfu/g. In contrast, at the same period, the titratable acidity increased significantly ($P < 0.05$) from 0.01% to 0.4% (Fig 1). Changes in acidity with time during fermentation were significant at a 95% confidence interval. High negative correlations exist between fermentation time and pH during steeping and souring. The increase in acidity and consequent drop in pH during the fermentation was likely due to the utilization of free sugars by LAB and yeasts involved in the fermentation. During the steeping period, there was an initial sharp drop in the level of reducing sugars, followed by a gradual rise. However, during the souring period, there was a continuous decrease in the reducing sugar level over time.

In terms of the microbial consortium, the population of moulds decreased significantly ($P < 0.05$) during fermentation from 6.8 log10 cfu/g at 0 h to 3.7log 10 cfu/g at 12 h of steeping; thereafter no mould population was observed again throughout the fermentation period (Fig 2). In contrast, a continuous and significant ($P>0.05$) increase in LAB and yeast population was observed throughout the fermentation period.

The LAB isolates were identified as *Lactobacillus fermentum, L. plantarum* and *L. brevis*. The yeasts were *Saccharomyces cerevisiae, Rhodotorula graminis, C. krusei, C. tropicalis, Geotrichum candidum* and *G. fermentum*. The moulds isolated were *Aspergillus niger, A. flavus, Rhizopus nigricans, Fusarium subglutinans* and *Penicillium citrinum*.

This study confirmed that lactic acid bacteria play a major role in *ogi* fermentation as previously reported by several authors (Teniola and Odunfa, 2001, Omemu *et al.,* 2007a) LAB numbers increased by 2–4 log units from the beginning to the end of fermentation, leading to acidification of the product. The rise in acidity and subsequent pH drop during fermentation was likely caused by the utilization of free sugars by the dominant microorganisms (yeasts and LAB). The significant ($p< 0.05$) reduction in the total sugar contents throughout fermentation may be due to starch breakdown into reducing sugars by amylolytic enzymes produced by some fermenting organisms. The elimination of moulds during the fermentation may be attributed to the presence of high numbers of LAB throughout fermentation, as bacteria have been reported to inhibit mould growth.

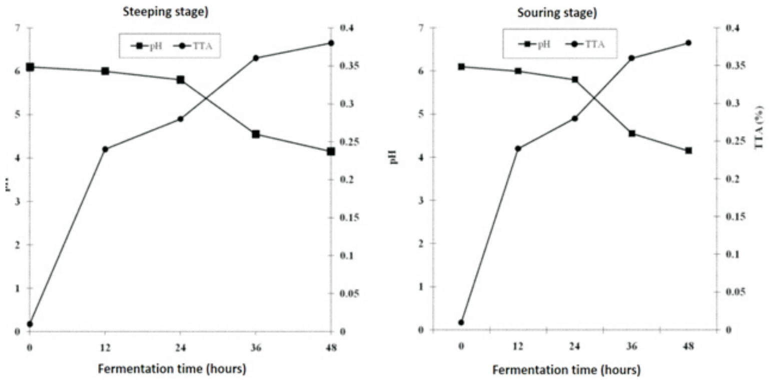

Fig 1: Acidity Changes During Fermentation of Maize for *Ogi* Production
Source: Omemu, 2011.

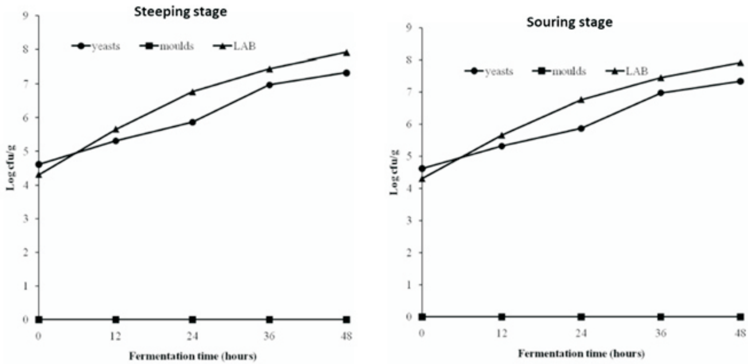

Fig 2: Growth Kinetics During the Fermentation of Maize for *Ogi* Production
Source: Omemu, 2011

2.1.1.2 Significance of Yeasts and Enzyme Production in Ogi Fermentation

Most studies have primarily focused on the role of lactic acid bacteria in the fermentation of maize for *ogi production* and there is a dearth of information on the role of yeasts. The presence of yeasts in the fermentation of other related cereal products such as kenkey, mawe, and fufu has been reported (Oyewole, 2001, Jespersen *et al*., 1994).

Omemu *et al.* (2007a) therefore studied the involvement of yeasts in *ogi* fermentation, particularly their enzyme production and interactions with lactic acid bacteria. Yeasts isolated and identified during the fermentation were screened for the production of extracellular enzymes (amylase, esterase, lipase, and phytase).

Results showed an increase in yeast population throughout the 48-h steeping period, a general reduction in yeast population after wet milling, and subsequently, a continuous increase in population during the souring stage. The mean values of yeast populations obtained with time were significant ($P<0.05$) while the type of yeast identified differed with time. While *Saccharomyces cerevisiae* dominated during the steeping stage especially at 0-12 hours and also at the beginning of souring; the later stage of souring was marked by the rapid proliferation of *Candida krusei, C. tropicalis, Geotrichum candidum, and G. fermentans.*

Our studies on enzyme production showed that representatives of all the yeast species isolated exhibited lipase and esterase activities. Only *S. cerevisiae* (2.60%) and *C. krusei* (7.41%) exhibited amylase activities. *Candida sp*. produced a wider zone of inhibition than the other yeasts strains tested during lipase activity while *S. cerevisiae* strains produced significantly ($p<0.05$) wider zone of clearing as compared to the other yeasts for esterase activities. All the yeast isolates except *Geotrichum fermentans* and *Rhodotorula graminis* were able to degrade phytate (Table 6).

The amylolytic capabilities of some of the yeasts suggest their contribution to breaking down maize starch into simple sugars for other fermenting microorganisms to use. High yeast counts coupled with esterase activities suggest that yeasts may be an important microbial group determining the aroma and flavour of *ogi*. Previous studies have indicated that *C. krusei* contributes significantly to the characteristic odour of fufu (Oyewole, 2001). It is likely that *C. krusei* also has a similar functional role in flavour development in *ogi*. Phytic acid found in cereal grains decreases the bioavailability of minerals like zinc, Iron, and magnesium. The ability of the yeast isolates to degrade phytate will allow better access to these nutritionally essential minerals; this is particularly beneficial for consumers of *ogi*. The result of the inter-relationships between *Lactobacillus plantarum* and yeasts (*C. krusei* and *S. cerevisiae*) showed that the growth of the yeast strains was enhanced during fermentation by the presence of the lactic acid bacteria, and the growth of the *L. plantarum* strain was significantly enhanced especially by the *C. krusei* (Fig 3).

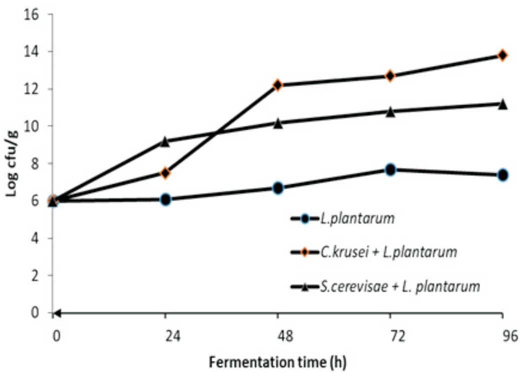

Figure 3: Growth of *L. plantarum* On Maize as a Single Pure Culture and When Inoculated as a Mixed Culture with *C. krusei* and *S. cerevisiae*. Source: Omemu *et al.* 2007a.

Table 5: Extracellular Enzyme Production by Yeasts Isolated During *'Ogi'* Production

Yeasts	**No of positive isolates (%)**				
	n	**Amylase**	**Lipase**	**Esterase**	**Phytase**
Saccharomyces cerevisae	77	2 (2.60)	39 (50.65)	54 (70.12)	5 (6.49)
Candida krusei	27	2 (2.41)	19 (70.37)	14 (51.85)	2 (7.41)
Candida tropicalis	8	0 (0.00)	6 (75.00)	4 (50.00)	1 (25.00)
Geotrichum candidum	15	0 (0.00)	9 (60.00)	4 (26.66)	5 (33.33)
Geotrichum fermentans	8	0 (0.00)	6 (75.00)	4 (50.00)	0 (0.00)
Rhodotorula graminis	10	0 (0.00)	2 (20.00)	5 (50.00)	0 (0.00)

Source: Omemu *et al.* 2007a

2.1.1.3 Diversity of fungi associated with stored ogi

The sensory characteristics of fermented products like *ogi* are as a result of interactions between various microorganisms. These interactions can be beneficial, shaping the desired flavor profile, or detrimental, leading to spoilage with off-flavours and discolouration. Due to the tedious processing method, *ogi* is usually prepared in bulk and stored for use. During storage at room temperature, the sour water can be decanted and replaced. However, this process leads to nutrient loss, and neglecting to replace the water can make *ogi* susceptible to fungal spoilage. Certain molds can proliferate on the product and produce harmful mycotoxins, while specific fungi may induce infections or allergies. Therefore, it's essential to identify the types of fungi present in *ogi* during storage.

Omemu *et al*. (2007b) identified the populations and profiles of fungi associated with *ogi* during storage until spoilage sets in. The parameters used to monitor spoilage were pH, total titrable acidity, total reducing sugars, dissolved hydrogen sulphide, ammonia level, and sensory analysis (Teniola and Odunfa, 2002).

The study noted an initial decrease in pH from 4.32±2.00 (day 1) to 3.16±2.14 by the 10th day, followed by a subsequent increase until the end of storage. Total reducing sugar levels declined consistently throughout the storage period. Increases in dissolved hydrogen sulphide and ammonia were observed until the 16th day of storage, after which they decreased. More hydrogen sulphide was produced during storage compared to ammonia. Sour water discoloration, which started on the 8th day of storage, intensified over time, coinciding with a decline in acceptability. By the 16^{th} day of storage without water change, the *ogi* sample was deemed unacceptable. All studied parameters showed significant changes over time ($p \leq 0.05$).

Mold was absent in both sour water and *ogi* samples until the 8th and 10th day, respectively, after which their populations steadily increased. Significant correlations between storage time and fungal populations were noted at 99% confidence interval (Tables 6 and 7).

Candida krusei, C. vini, Geotrichum candidum, and *Pichia japonica* were the dominant yeasts during the storage of *ogi*; this was followed by an increase in pH and a reduction in total acidity. *Candida* sp. has been implicated in decreasing the acidity of fermented foods thereby promoting spoilage by other microorganisms. Discolouration of stored *ogi* coincided with mould isolation. Fungi such as *Aspergillus niger, Aspergillus flavus, Rhizopus nigricans*, and *Penicillium sp*. were dominant by the 20th day of storage. These moulds are known for their ability to produce mycotoxins, including aflatoxin B1, fumonisin B1, ochratoxin A, trichothecenes, and zearalenone which can be toxic to humans and livestock even in small concentrations.

This study suggests molds and yeasts may play a more significant role than previously acknowledged in spoilage, highlighting the importance of understanding and managing microbial ecology during production and storage to mitigate mycotoxin contamination and ensure safety.

Table 6: Changes in the Parameters Used to Monitor Spoilage During the Storage of '*Ogi*'.

Storage days	pH±SE*	TTA (%)±SE*	H_2S±SE*	Ammonia±SE*	Reducing sugars±SE*	Total acceptability±SE*
1	4.32±0.4	0.02±0.0	0±0.0	0±0.0	3.2±0.6	9±0.3
2	3.65±0.3	0.35±0.01	10±0.7	20±1.9	2.8±0.4	8±0.5
4	3.10±0.4	0.52±0.02	40±1.2	40± 3.4	2.6±0.5	7±0.6
6	3.14±0.2	0.44±0.01	62±2.4	60±3.8	1.5±0.6	7±0.4
10	3.18±0.2	0.32±0.01	100±6.7	85±2.9	1.2±0.6	5±0.4
14	3.20±0.3	0.25±0.02	220±5.4	100±5.6	1.0±0.4	2±0.1
16	3.30±0.5	0.23±0.01	250±4.6	150±4.5	0.8±0.1	0±0.0
18	3.66±0.6	0.21±0.02	240±4.8	120±4.9	0.6±0.05	0±0.0
20	3.71±0.4	0.19±0.02	230±3.9	100±3.4	0.4±0.02	0±0.0

*Mean of triplicate determinations±standard error

Source: Omemu *et al.* 2007b.

Table 7: Changes in Yeasts and Mould Population During the Storage of *Ogi*

	Corn steep liquor		*ogi*	
Storage days	Yeast population*	Mould population*	Yeast population*	Mould population*
1	4.62±1.05	0.00±0.00	3.51±0.25	0.00±0.00
2	6.92±1.55	0.00±0.00	3.63±0.15	0.00±0.00
4	7.93±5.50	0.00±0.00	4.80±3.25	0.00±0.00
6	7.96±1.77	0.00±0.00	5.71±3.37	0.00±0.00
8	8.81±2.29	0.00±0.00	6.32±1.00	0.00±0.00
10	8.85±2.36	2.51±2.00	6.80±2.00	0.00±0.00
12	8.96±2.00	3.82±0.20	6.93±1.00	$<10^2$
14	8.87±2.00	4.46±1.52	7.33±1.00	2.08±0.21
16	7.87±2.00	5.14±0.60	6.87±0.20	3.81±0.45
18	6.62±2.20	6.82±2.20	6.54±2.00	4.51±2.00
20	4.72±3.00	8.80±2.00	4.65±1.40	6.74±2.00

*Mean of triplicate determinations (log cfu g^{-1})±standard error

Source: Omemu *et al.* 2007a

2.1.1.4 Probiotic potential and safety profile of isolates from effluent generated during ogi production

Probiotics are preferred over antibiotics for treating infections due to concerns about bacterial resistance from prolonged antibiotic use. Olatunde, Obadina, Omemu, Oyewole, Olugbile and Olukomaiya (2018) carried out screening and molecular identification of potential probiotic lactic acid bacteria in effluents generated during *ogi* production. The safety of the isolates was tested by examining their antagonistic activity against selected pathogens (*Escherichia coli, Staphylococcus aureus,* and *Salmonella typhimurium*) in vitro.

Results of the study showed that out of the 88 LAB isolated from the effluents, 10 survived pH 1.5 and were also viable at 0.3% bile salt concentration. The zones of inhibition of the LAB isolates with probiotic potential ranged from 7.00 to 24.70 mm against the test organisms (Fig 4 and Fig. 5). Using molecular methods, the identity of the probiotic potential LAB isolates was confirmed to be *Lactobacillus plantarum, Lactobacillus fermentum, Lactobacillus reuteri, Enterococcus faecium, Pediococcus acidilactici, Pediococcus pentosaceus, Enterococcus faecalis,* and

Lactobacillus brevis.

Before reaching the intestinal tract, probiotic bacteria must first survive transit through the stomach where the pH can be as low as 1.5 to 2.0. These characteristics allow the organisms to be established, survive, grow, and perform their actions in the gastrointestinal tract of the hosts. Tolerance to low pH and bile acids is considered e a prerequisite for colonization and metabolic activity of bacteria in the small intestine of the host hence the findings of this study suggest that LAB isolated from *ogi* effluents have potential as probiotics for both research and commercial applications.

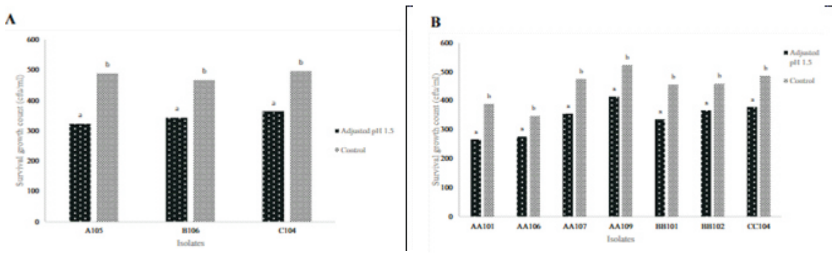

Fig. 4: Survival Rate Count of LAB Isolates Obtained from Effluents Generated During First Fermentation (A) and Second Fermentation (B) in *Ogi* Production That Survived pH 1.5 Compared With the Control.
Source: Olatunde *et al.* 2018

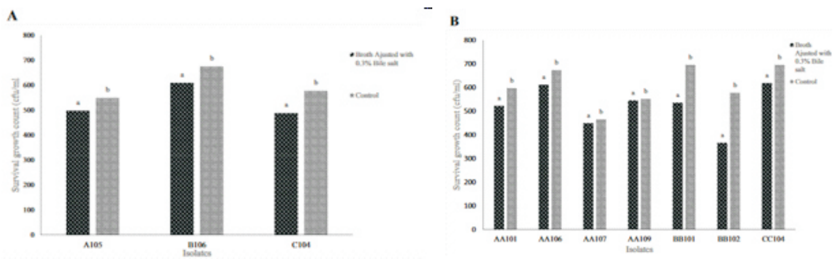

Fig. 5: Survival Rate Count of LAB Isolates Obtained from Effluents Generated During First Fermentation (A) and Second Fermentation (B) in *Ogi* Production That Survived *Bile Salt 0.30% Compared with Control.* Source: Olatunde *et al.* 2018

2.1.1.5 Antimicrobial potentials of microorganisms associated with omidun, the supernatant solution of fermented maize

Diarrhea remains a major health concern in developing countries, predominantly affecting children under five years old. WHO guidelines recommend oral rehydration therapy and intravenous fluids for severe dehydration for diarrhea treatment. In certain cases of bloody, or persistent diarrhoea, antimicrobial therapy may be necessary (Trevor, *et al.,* 2013). However, the rise of antibiotic-resistant pathogens poses challenges to effective treatment, especially in resource-limited settings. *Omidun*, the sour water derived from *ogi* holds traditional medicinal value, reportedly used for herbal extraction and also popularly used in managing diarrhea and gastroenteritis.

Based on this, Falana, Bankole, Omemu, and Oyewole **(**2012) and (2016)conducted studies to determine the antimicrobial activity of certain microorganisms typically found in omidun. These microorganisms were tested individually and in combination against two known gastroenteric bacteria(E. coli ATCC 25922 and Salmonella abaetetuba ATCC 35460)*,* with commercial antibiotics used as controls**.** The test organisms were typed cultures obtained from Lagos University Teaching Hospital (LUTH).

Results of our studies indicated that the type of maize (white and yellow) from which *omidun* was prepared did not affect the antimicrobial activity against the gastroenteric bacteria. However, the microorganisms isolated from *omidun* have varied antimicrobial activities against the tested organisms. *Lactobacillus plantarum* demonstrated significant inhibition against *E. coli* ATCC 25922 (32 mm) and *S. abaetetuba* ATCC 35460 (28 mm), surpassing those of commercial antibiotics. This suggests the potential of *L. plantarum* for controlling gastroenteric *E. coli* and *S. abaetetuba*. The observed inhibitory effect is likely attributed to antimicrobial compound production by *L. plantarum* (Falana *et al.,* 2012, 2016).

2.1.2 Safety Assessment of Yam (Dioscorea spp.) Products

Yam, the third most consumed crop in the Sub-Saharan region, especially in West Africa, is very much perishable due to microbe-induced rotting. To minimize losses, freshly harvested yams are usually processed into dry products such as chips and flakes which are produced through peeling, slicing, blanching, steeping, and sun-drying. The dry yam slices (gbodo) are then milled to produce traditional yam flour (elubo) which is prepared by cooking in boiled water to give a viscous smooth paste called amala. Small and medium-scale processors, including cottage and rural processors, predominantly produce yam chips, flakes, and flour using non-standardized methods. This results in varying quality of final products, raising safety concerns.

Consequently, Omohimi et al. (2019) evaluated the safety of dried yam products, with a focus on bacterial, fungal, aflatoxins, pesticides, and heavy metals such as lead, cadmium, nickel and mercury contamination. Results showed that microbial contamination was observed in all samples, but freshly processed samples have significantly ($p>0.05$) lower levels of contaminants. Heavy metal concentrations (particularly *lead*, *cadmium*, and *nickel*) were higher in market samples, especially in yam flour, compared to those obtained directly from processors. Aflatoxin was not detected in freshly produced foodstuffs, but higher levels were found in some market samples. No pesticides were detected in any of the samples.

Our study identified the drying step as the most critical factor for microbial contamination of yam-derived products. Post-processing steps, such as storage, exposure at the point of sale, and vehicular emissions may also contribute to contamination since most of the processors dry the yam by the roadside where there is high vehicular movement. We recommended enhanced hygiene practices during drying, display and sale. Education of processors and collaboration with regulatory bodies to ensure compliance is also important to ensure the production of safe, high-quality yam-derived products.

2.1.3 Influence of Milling on the Microbiological Quality of Yam Flour

Somorin, Bankole and Omemu (2011) examined the influence of milling process on the microbiological quality of yam flour (*Elubo*). Dry yam chips samples obtained from different markets were milled using milling machines available in the markets while other sets were milled using sterilized milling machines in the laboratory. Swabs from the commercial milling machines used for milling yam flour in the markets exhibited varying levels of microorganisms hence yam flour from market milling had higher microbial loads compared to that milled in the laboratory.
Generally, the total viable bacterial count of laboratory-milled yam flour was significantly lower ($p<0.05$) than that milled at the commercial milling machines available in the markets. *Staphylococcus aureus, Enterobacter aerogenes, S. saprophyticus, Bacillus megaterium, B. badius* and *Corynebacterium* spp. were found to commonly contaminate the yam flour (Table 8). All the commercially milled yam flour samples had microbial load that exceeded recommended microbial levels by the International Commission on Microbiological Specifications for Foods (ICMSF, 2002). This was attributed to contamination of the dry yam chips and the milling machine, milling methods, cross-contamination, and unhygienic practices by processors. Some processors crushed yam chips on dirty floors before grinding them into flour. In addition, milling machines are often used for various dry cereals, not just yam chips, and irregular sanitization resulting in residue buildup which contributes to cross-contamination risks.

The isolation of *Bacillus* species in some samples of the yam flour in this study raises some concern since *Bacillus* spp are known for production of toxin, such as cereulide, a heat-stable toxin causing a vomiting-type syndrome (Hoton *et al.,* 2009). Reports of food poisoning, particularly affecting children in Nigerian families, after consuming yam flour meals underscore the seriousness of the issue. Additionally, certain molds isolated in this study are reported toxin producers, linked to immune suppression, liver cancers, and fatalities (Probst *et al.,* 2007).

We suggested that processors of yam flour should be educated on the importance of regular cleaning of their milling machines and avoid the collection of flour spilled on the floor into the batch to be consumed by humans. Also, inspection of processing units by responsible government agencies will ensure that the best practices are complied with and consumers will have access to safer yam flour.

Table 8: Total Bacterial Count and Microorganisms Isolated from Milling Machines Used In Yam Flour Processing

Location	Total viable bacterial count (cfu cm^{-1})	Bacteria isolated	Fungi isolated
Abeokuta	1.32×10^{3c}	*Enterobacter aerogenes*, *Bacillus megaterium*, *Staphylococcus epidermidis*, *S. saprophyticus*, *Klebsiella oxytoca*	*Aspergillus flavus*, *A. niger*, *Penicillium oxalicum*, *A. fumigatus*, *Fusarium verticillioides*, *Rhizopus oryzae*
Ibadan	2.1×10^{2a}	*S. aureus*, *S. epidermidis*, *B. badius*, *Corynebacterium* spp. *B. megaterium*,	ND
Mushin	1.63×10^{3b}	*K. pneumoniae*, *B. megaterium*, *S. epidermidis*, *Proteus mirabilis*, *Corynebacterium* spp.	*R. oryzae*, *P. oxalicum*, *A. niger*, *A. flavus*, *P. citrinum*, *Mucor* spp.

ND: Not determined. Means within column with the same letter are not significantly different ($p>0.05$)

Source: Somorin *et al.* 2011

2.1.4 Safety assessment of fermented cassava flour 'lafun'

Cassava (*Manihot esculenta Crantz*) is a major root crop in the tropics. *Lafun* is a fine flour obtained from the traditional fermentation of cassava and the processing involves peeling, cutting, submerged fermentation, dewatering, sun drying, and milling. There are reports on the high rate of spoilage, as well as toxicity resulting from the consumption of *lafun*.

Adebayo-Oyetoro, Oyewole, Obadina, and Omemu (2013) assessed the microbiological safety of *lafun* obtained from processors and sellers in selected markets and processing sites in Ogun and Oyo States, Nigeria. Processing water from boreholes, rain, and streams was also collected. All samples were analyzed for total plate count, fungi and coliform count.

Results revealed that contamination of *lafun* was mostly due to poor handling during processing or in the markets. During this study, we observed sun drying of *lafun* by roadsides or on bare floors and sometimes near animal-rearing areas. In some cases, toilets are located near processing areas, facilitating cross-contamination. Some processors also reduced the length of time for fermentation to meet high customer demand. Shortening fermentation time also increases the risk of microbial contamination, compromises product quality, results in shorter shelf life, and causes gastrointestinal problems for consumers. The displayed pattern in the market where *lafun* is usually displayed in open containers without cover also encourages cross-contamination.

We recommended the provision of piped water or boreholes for consistent water supply during processing, provision of modern dryers in each community; education of processors on good hygienic practices, and close monitoring by health officials to ensure strict compliance by processors and market sellers.

2.1.5 Safety assessment of iru and 'ogiri'

Traditional fermented foods made from legumes and oilseeds often used as condiments play a vital role in providing protein to several households in rural Africa and Asia. However, their production, is primarily small-scale and household-based, relying on spontaneous fermentation which can impact product quality. In Nigeria, African locust bean seeds and oil-rich seeds undergo spontaneous fermentation to produce *iru* or *Dawa Dawa* and *ogiri* respectively.

2.1.5.1 Bacteria isolated during the processing of iru and ogiri.

Consumption of *iru* and *ogiri* is growing, reinforcing the need to scale up their production. Production of these condiments includes spontaneous fermentation, which often leads to inconsistent product quality and unguaranteed safety. Understanding bacterial dynamics during fermentation is crucial for ensuring safety, quality control, and advancing starter culture technology. Hence, Ademola, Adeyemi, Ezeokoli, Obadina, Somorin, Omemu, Oluwafemi, and Oyewole, (2018) carried out a study to characterize the bacteria associated with the processing of *iru* and *ogiri* condiments based on the phylogenetic analyses of the bacterial 16S rRNA gene.

A total of 227 isolates were identified and clustered into 12 operational taxonomic units (OTUs) based on 97% 16S rRNA gene similarity, spanning three phyla (Firmicutes, Actinobacteria, and Proteobacteria) and nine genera (*Acinetobacter, Aerococcus, Bacillus, Enterococcus, Enterobacter, Lysinibacillus, Micrococcus, Proteus,* and *Staphylococcus*). OTUs closely related to species of *Bacillus* dominated the processing stages of both condiments. No single OTU persisted throughout the stages of *iru* processing while one OTU (primarily linked to *B. safensis*) dominated the *ogiri* processing stages, suggesting its potential as a starter culture. Additionally, isolates such as *Enterococcus* spp. and *Lysinibacillus* spp. could serve as potential starters for *iru* fermentation.

This study reveals the bacterial progression in the processing of *iru* and *ogiri*, identifying species suitable for developing starter cultures and ultimately promoting the production of safe, high-quality *iru* and *ogiri* condiments.

2.1.5.2 Mycotoxin contamination of locust bean, melon, 'iru' and 'ogiri'

Previous research has established that the ultimate microbiological quality and safety of spontaneously fermented food products are affected by several factors, including the quality of the raw materials and the hygiene practices of the personnel involved in the fermentation process (Iwuoha and Eke, 1996). Adedeji *et al.* (2017) therefore assessed the mycotoxin contamination associated with *iru* and *ogiri* as well as their raw materials (locust bean, melon) purchased from markets in southwest, Nigeria.

Through 16S rRNA gene sequencing and liquid chromatography-tandem mass spectrometry (LC-MS/MS), 200 isolates from the samples were clustered into 10 operational taxonomic units (OTUs), spanning three phyla, 10 genera, 14 species, and 2 subspecies. *Bacillus* and *Staphylococcus* were the predominant genera. Presence of potentially pathogenic species like *Alcaligenes faecalis*, *Bacillus anthracis*, *Proteus mirabilis*, and *Staphylococcus sciuri* subsp. sciuri indicated poor hygiene during production or handling.

The analysis also identified 48 microbial metabolites, including 7 mycotoxins, with aflatoxin present in melon and *ogiri* samples but absent in locust beans and *iru*. Although mycotoxin levels were generally low, the findings highlight the importance of educating processors and vendors on good hygiene and processing practices.
It is worthy of note that this work was supported by the South African National Research Foundation Thuthuka grant #841688 for molecular characterization and the MycoMarker project (BOKU Research Funding) for mycotoxin analysis.

2.2 Safety on the Farm

Food safety and Hygienic practices (FSH) are Good Agricultural Practices with bias for food safety on the farm. The concept of FSH evolved recently as a result of the big concern about food safety and quality, and the environmental sustainability of agriculture. The benefits of FSH include improved consumer safety, quality assurance, regulatory compliance, environmental sustainability, consumer trust, market access, and agricultural viability.

Oyinlola, Obadina, Omemu and Oyewole (2017) with the support of My Community, Our Earth (MyCOE) / SERVIR Fellowship Program sponsored by AAG, USAID, and SERVIR, therefore assessed the impact of adopting FSH by lettuce farmers on microbial safety in Lagos State, Nigeria. Questionnaire was used to select farms practicing FSH and those not practicing it. The respondents are farmers who received technical support from the Lagos State Ministry of Agriculture with a focus on organic production practices and chemical hazard control, particularly pesticide residue. Samples of ready-to-harvest lettuce, applied manure, and irrigation water were collected over five months, analyzed for various microbial indicators, and the results of lettuce samples were compared with international microbiological specifications for ready-to-eat foods.

Our results showed that compliance with food safety hygiene practices among farmers varied. A significant ($p<0.05$) percentage of lettuce farmers applied raw cow dung (70%) and raw poultry droppings (53%) to their crops, but none used human waste. All respondents reported using composted manure, but none had measures in place to prevent indirect manure contamination from neighbouring farms. None of the farmers cleaned containers before reusing them for harvest. Lower microbial counts were observed in FSH farms compared to non-FSH farms. *Listeria spp*. counts in lettuce samples exceeded satisfactory limits, and irrigation water also did not meet the minimum criteria for fresh produce irrigation (WHO, 2006). There was a significant positive correlation between *Listeria* spp. counts in irrigation water and lettuce samples, indicating potential contamination (Table 10).

The high level of *Listeria* spp in the lettuce sample is worrisome because *Listeria monocytogenes* can cause severe foodborne illness, particularly in pregnant women, the elderly, and the immunocompromised. Consumption of vegetables contaminated with high levels of *Listeria monocytogenes* by pregnant women can lead to miscarriages, stillbirths, premature delivery, or life-threatening infections in newborns.

This study emphasizes the importance of Food Safety and Hygienic practices in enhancing the microbial safety of lettuce and other vegetables for public consumption and highlights the need for educating farmers and handlers on Good agricultural practices on the farm.

Table 9: Correlation of *Listeria* spp. in Lettuce, Manure and Irrigation Water Over Season

Listeria spp.	Lettuce	Rainfall	Temp.	RH	Manure	Water
Lettuce	1.000					
Rainfall (mm)	0.087	1.000				
Temp.(0^C)	- 0.054	- 0.207	1.000			
RH (%)	0.268	0.326	- 0.459[t]	1.000		
Manure 0.085	- 0.200	0.266	- 0.082	1.000		
Water	0.377[t]	0.241	0.185	- 0.017	- 0.411[t]	1.000

RH, relative humidity

[t]Correlation is significant at the 0.05 level (two-tailed).

Source: Oyinlola, Obadina, Omemu and Oyewole (2017)

2.3 Safety of Food on the Streets and Retail Stores

Food safety in both street vendors and retail stores is crucial for public health. The street food industry, particularly in countries like Nigeria, offers significant benefits such as affordable, convenient, and often nutritious food. However, studies have linked street foods and their handlers to various foodborne illnesses, highlighting the importance of stringent hygiene practices and regulations to mitigate risks to consumers (Edema and Omemu, 2004).

2.3.1 Safety assessment of street vended 'wara' - Nigerian white cheese

'Wara' is a soft, white, unsalted cheese made from cow milk by the Fulani tribes in Nigeria. It is processed from unpasteurized milk using *Calotropis procera* juice extract, serving as both a means of preservation and nutrient retention. However, outbreaks of foodborne illnesses linked to unpasteurized or improperly pasteurized milk products highlight the public health concern

regarding *wara* cheese, particularly when sold by street vendors lacking food safety education. Hence, Omemu, Obadina, Taiwo and Obuotor (2014a) assessed the microbial characteristics and prevalence of foodborne pathogens in street-vended *wara* cheese in Abeokuta, Nigeria.

Results indicated significant ($p<0.05$) variations in microbial populations among vendors, with high counts of *Staphylococcus aureus*, presumptive *E. coli*, and *Bacillus cereus* detected in samples suggesting poor hygiene during production, fecal contamination, and inadequate temperature control during processing or storage. However, none of the samples analyzed contained *Vibrio cholerae*. Identified sources of contamination included raw milk, inadequate pasteurization, post-pasteurization contamination, and poor hygiene practices during processing and handling. Addressing these concerns requires implementing strict hygiene practices, improving sanitation measures, ensuring proper temperature control, and educating producers and consumers about safe food handling.

2.3.2 Safety assessment of street-vended ready-to-eat vegetable salad

Salads, composed of raw vegetables packed with nutrients, are popular dietary choice. However, their safety can be compromised by factors related to both preparation and consumption environments. In a study conducted by Omemu, Edema, and Bankole (2005), the bacterial status of ready-to-eat (RTE) vegetables and prepackaged salads sold on the streets of Lagos was investigated.

The results revealed high counts of aerobic bacteria and coliforms in the samples, likely stemming from poor handling and hygiene practices during salad preparation. Predominant bacterial species included *Staphylococcus, Enterobacter,* and *Bacillus cereus*.

Notably, *Listeria* spp. was identified in lettuce and carrot samples, all of which are known foodborne pathogens. While street foods offer affordable meals and income opportunities for vendors, they also pose significant health risks.

2.3.3 Safety of powdered infant formula in retail stores

Breast milk is widely acknowledged as the best nutrition for infants, but Powdered Infant Formula (PIF) is often used as an alternative. Despite a common misconception that powdered infant formula (PIF) is sterile, numerous studies (Bogdanovicova *et al.,* 2007) have confirmed the presence of microorganisms. This raises safety concerns, as potential pathogens could survive production and multiply after rehydration, posing a risk especially in preterm, low-birthweight or immuno-compromised infants. While no reported outbreaks in Nigeria link bacterial contamination to powdered infant formula (PIF), and existing surveillance data is lacking, the microbiological safety of PIF consumed by infants in Lagos remains uninvestigated.

Oyetibo, Shittu, and Omemu (2022) aims to bridge this gap by examining the potential presence of harmful bacteria in PIF. Sample (172) of PIF from 38 brands were analyzed using a culture-independent approach targeting specific regions of the 16S rRNA genes (V1-V3 regions). The PIF analyzed have production date less than six months and none of them was expired.

Our result revealed a high population of bacteria per gram of PIF with lower diversity in terms of different species (Table 10). A total of 60,876 sequence reads were obtained, comprising 2 dominant phyla: Firmicutes (85.2%) and Proteobacteria (14.8%), mainly composed of *Bacillus* and *Enterobacter* genera. The most prevalent species included *Bacillus amyloliquefaciens, Enterobacter asburiae,* and *Enterobacter cloacae.* Some identified taxa were from human gut bacteria, including potential pathogens like *Cronobacter sakazakii, Klebsiella pneumoniae, Salmonella enterica,* and *Alcaligenes faecalis*, although in low abundance.

The absence of inscriptions indicating non-sterility on PIF labels suggests a misconception regarding the sterility of Powdered Infant Formula (PIF) in Nigeria. Clear labelling regulations should be implemented to indicate the non-sterility of PIF. When reconstituted powdered infant formula is prepared and stored incorrectly, it is possible for bacteria to grow (Agostoni *et al.,* 2004), hence, public awareness campaigns targeting caregivers and healthcare professionals are essential to promote proper hygiene practices during the rehydration and storage of PIF.

Table 10: Diversity Indices of Bacteria Associated with Powdered Infant Formula

Indices	Actual	HCI	LCI
Valid reads	60,876	ND	ND
OTUs	138	ND	ND
Ace	143.955	151.044	137.638
Chao1	140.538	149.368	138.567
JackKnife	150.000	150.0	150
NPShannon	1.100	ND	ND
Shannon	1.099	1.114	1.085
Simpson	0.613	0.617	0.608
Good's Lib. Coverage	99.980	ND	ND

Source: Oyetibo *et al.,* 2022

2.4 Food Handlers and Food Safety

Food handlers, often referred to as food vendors, constitute essential elements in the interface between the food preparation environment and the food itself. WHO (1989), defined food handlers as individuals who, as part of their regular work duties, manage food or items that could potentially come into contact with food, including utensils designed for eating and drinking that are not intended for their personal use. The health of food handlers is paramount to maintaining food safety standards and preventing the spread of foodborne illnesses. Numerous reports have suggested that infected food handlers can play a critical role in food contamination and the occurrence of foodborne disease outbreaks (Rose and Slifko, 1999; Omemu and Aderoju, 2008).

2.4.1 Microorganisms associated with the palms of food handlers

Although the overall well-being of food handlers is crucial for food safety, their hands are particularly critical as potential sites for microbial presence, posing a significant risk for cross-contamination, especially among unwell or pathogen-carrying individuals.

A 2005 preliminary investigation we carried out revealed a state-issued memorandum in Ogun state aimed at regulating street food vending. According to this memorandum, food handlers were required to obtain health certificates from authorized hospitals after undergoing thorough physical and medical examinations. These certificates were to be kept by the vendors, presented on demand to health officers, and renewed annually.

A study by Bankole, Omemu, and Oladimeji (2009) evaluated food handlers' adherence to the recommended annual medical examination and assessed the presence and types of microorganisms on their palms. The study involved food handlers from informal (streets) and formal (restaurants and hotels) establishments in Abeokuta, categorized into six groups based on their vending sites. Palm swab samples were collected and analyzed for total aerobic plate counts, *Staphylococcus aureus*, *Bacillus cereus*, and Enterobacteriaceae counts. A health officer accompanied researchers on sampling days to request health certificates from the food handlers before sampling.

Our study found that over half (56.3%) of the sampled food handlers did not undergo the annual medical routine check-up (Table 11). None of the hawkers underwent the check-up, possibly due to illiteracy and ignorance, but all hotel food operators complied, likely because it is compulsory under Nigerian law for establishing hotels. Many food vendors perceived medical tests as unnecessary until they became visibly ill and required medical attention.

Higher microbial loads were observed on the palms of hawkers compared to other food handlers, while hotel food handlers had the lowest counts (Table 12). This difference was attributed to the cleaner operating environments in restaurants and hotels which provide access to sanitation facilities. In contrast, vendors in other settings lacked such amenities, leading to unhygienic practices like using secluded areas as makeshift toilets and a shortage of water for proper handwashing. Such conditions and practices often led to contamination of the hands and ultimately cross-contamination of cooked foods.

The types of microorganisms isolated from the palms of the food handlers were resident microflora, which are normal microorganisms found on the skin or in the body of healthy individuals and typically do not cause foodborne illness. However, the presence of coliforms (*Enterobacter sp., E. coli, Klebsiella aerogenes, Proteus vulgaris,* and *Shigella sonnei*) on some food handlers' palms indicated fecal contamination, possibly due to inadequate and improper handwashing or contact with contaminated raw products.

Overall, the study suggests that food handlers' hands may serve as sources of microorganisms implicated in foodborne illness and food spoilage. It highlights the importance of proper sanitation infrastructure in food handling establishments and emphasizes the need for enforcing annual physical and medical examinations for food vendors. Education on personal hygiene practices among food handlers is recommended to mitigate the risk of foodborne diseases.

Table 11:Numbers and Percentages of Food Handlers with and Without Medical Certificate

Category of Food handlers	n	Vendors with health certificate	Vendors without certificate
Hawkers	15	0 (0)	15 (100.0)
Roadside	13	2 (15.4)	11 (84.6)
Open air	15	7 (46.7)	8 (53.3)
Roofed/closed canteen	21	10 (47.6)	11 (52.4)
Restaurants	12	8 (66.7)	4 (33.3)
Hotels	11	11 (100)	0 (0)
Total	87	38 (43.7)	49(56.3)

n- number sampled
Values in parenthesis represent the percentage of occurrence
Source: Bankole, Omemu, and Oladimeji (2009)

Table 12: Mean (Log Cfu/ G) Level of Microbial Contamination on the Palm of Food Handlers

Category of food handlers	n	Total counts log cfu + SD*	Enterobacteriaceae log cfu + SD *	S. aureus log cfu + SD*	Bacillus sp log cfu + SD *
Hawkers	15	7.2 + 0.7	4.5 + 1.2	5.2 + 1.2	3.4 + 0.1
Roadside	13	6.3 + 1.6	4.2 + 1.7	6.1 + 1.1	3.6 + 0.05
Open air	15	6.8 + 0.6	5.0 + 1.1	4.5 + 1.2	3.2 + 0.02
Roofed/ closed canteen	21	7.0 + 0.7	4.7 + 1.2	4.7 + 1.3	1.6 + 0.9
Restaurants	12	2.2 + 0.05	2.7 + 0.09	2.7 + 0.2	0.3 + 0.01
Hotels	11	1.4 + 0.1	2.6 + 1.2	1.3 + 0.4	<1.0

n- number sampled
* mean of triplicate readings ± standard deviation

Source: Bankole, Omemu, and Oladimeji (2009)

2.4.2 Incidence of enteric bacteria in food handlers

Food handlers can be symptomatic or asymptomatic carriers of food-borne infections. Both the transmission of norovirus and *Salmonella enteritidis* have been attributed to asymptomatic food handlers. Omemu and Oloyede (2014) carried out a study to determine the incidence of enteric bacteria by screening the fecal samples of healthy food handlers using the stool culture method. The study, conducted for 6 months, involved 200 food handlers working in small food businesses around primary schools, hospitals, and roadside sheds around different offices. Food handlers with fever, diarrhea, headache, abdominal pains, or symptoms of active enteric disease were excluded from the study.

Half (50.9 %)of the food handlers sampled were positive for enteric bacteria. *Escherichia coli (*17.7%), *Klebsiella oxytoca (*7.7%), *Salmonella spp* (5.5%*), Citrobacter freundii* (4.4%), *Enterobacter cloacae* (2.8%), *Pseudomonas aeruginosa* (8.3%) and *Proteus mirabilis* (4.4%) (Table 13).

The presence of Salmonella in the feces of food handlers in this study poses a significant risk to food safety, as people infected with *Salmonella* can shed the bacteria in their feaces even without symptoms and they can potentially contaminate food if proper hygiene measures are not followed. Strict adherence to hygiene protocols is crucial to prevent food contamination. Education and continuous training of food-handling personnel in good hygiene practices are recommended.

Table 13. Frequency of Occurrence of Enteric Isolates from the Food Handlers

Isolates	**Community**	
	Frequency (n)	**Percentage (%)**
Eschericial coli	32	17.7
Klebsiella oxytoca	14	7.7
Salmonella spp	10	5.5
Citrobacter freundii	8	4.4
Enterobacter cloacae	5	2.8
Pseudomonas aeruginosa	15	8.4
Proteus mirabilis	8	4.4
None	89	49.1

Source: Omemu and Oloyede, 2014

2.4.3 Food safety knowledge, attitude and practices of street food handlers

Omemu and Aderoju (2008), and Omemu and Oloyede (2014) conducted a survey to assess the food safety knowledge, and attitude of street food vendors in Abeokuta. The majority (78%) of the respondents were female, aged between 31 and 40 years. About

18% had no formal education, while 45% had at least primary school education. Most vendors acquired knowledge of food preparation through observation rather than formal education. Despite having been in the food vending trade for over six years, 69% of the vendors could not present the mandatory health certificate, indicating a lack of compliance with annual medical check-ups. Although most vendors knew the importance of handwashing, this knowledge was not consistently put into practice, likely due to limited access to water, handwashing, and toilet facilities at vending sites.

The study revealed that majority of food handlers had received some form of training on personal (71.3%) and general hygiene (75.1%), primarily organized by the workplace. Only 53.6% and 17.7% reported illnesses and injuries at work to management, indicating a potential underreporting issue. Furthermore, 30.4% claimed that no action was taken by management when a staff member fell ill, suggesting a need for improved management practices.

A finding of concern was that most vendors were unaware of the need to abstain from cooking or vending when afflicted with an infectious ailment because they prioritize the economic aspects of their trade over public health concerns. Most of the vendors also believed that the risk of spreading the infection was outweighed by their culinary prowess. Many vendors focused more on the volume and price of raw materials rather than their freshness and cleanliness, sometimes opting for lower-quality ingredients to reduce costs. The source of raw materials was highlighted as crucial, as contamination could persist through preparation.

The study underscores the necessity of developing a code of practice for street food vendors to enhance food safety. It also emphasizes the importance of vendor education, as street food vendors in many developing countries, including Nigeria, are often not adequately organized or responsive to the responsibility of their training.

2.4.4 Food safety knowledge, attitude and practices food handlers in eateries and restaurants

Omemu *et al.* (2014) examined the knowledge, attitudes, and practices of food service staff in selected fast food outlets in Abeokuta. A significant portion (53%) of respondents had tertiary education, with 70% acquiring food preparation knowledge through formal training. Additionally, 45% had 6 to 10 years of experience in the food industry; however, only 28% possessed health certificates indicating they underwent annual medical checkups. The study found that the majority of food service staff had adequate knowledge regarding food-borne pathogens, food preparation, and sources of contamination. Notably, they exhibited good hygiene practices, particularly regarding handwashing, likely due to the availability of hand washing facilities in fast food outlets compared to street food vendors.

The study also observed a positive attitude among staff towards safe storage practices, personal hygiene, and willingness to adopt better food safety practices. Overall, the surveyed staff demonstrated moderate knowledge (69.06%), positive attitude (84.0%), and satisfactory practice (60.35%) in food safety. Furthermore, a significant portion (86%) believed that food safety knowledge would impact both their professional and personal lives. The authors recommended continuous education and training for food handlers to maintain and improve their food safety standards.

2.4.5 Perceptions of mothers and safety of food prepared in homes

Multiple studies indicate that a significant portion of foodborne illnesses stem from home kitchen practices. Omemu *et al.* (2011) investigated food safety practices among mothers with children under 5 years old and microbial contamination in traditional complementary foods in rural households in Alabata, Ogun state, and Ikola, Lagos state.

Result shows that only 11% of mothers had tertiary education, with none receiving formal food preparation or safety training. Most (53.8%) learned cooking from their parents, and 21.7% through practice. While 85% of mothers washed their hands before handling food or feeding children, soap usage was limited. Storage facilities for cooked food included food warmers, bowls, and refrigerators.Common complementary foods include *ogi, amala*, rice, beans, *eba*, and *eko*. Microbial counts varied among foods, with *eko* showing the highest count (7.01 ± 0.17 log cfu/g) and *amala* the least (3.42 ± 0.22 log cfu/g). This may be because *amala* is usually eaten hot and is rarely stored for more than a few hours. In contrast, the preparation of *eko* is laborious, hence eko is mostly purchased from vendors and can be stored for several days before consumption. Factors like food preparation, storage practices, and reheating influenced contamination levels more than the food type. More of stored unheated food are contaminated compared to freshly cooked foods (Fig. 6). Isolated microorganisms included *Escherichia coli, Bacillus cereus, Staphylococcus aureus, Enterococcus faecalis, Aspergillus niger*, *Mucor mucedo*, and *Penicillium species*. Household practices, such as storing food at ambient temperature for prolonged periods, increased the risk of foodborne illnesses, even with initially high cooking temperatures.

Educating individuals on temperature control, proper storage, and reheating of foods is crucial for global food safety. Home food preparers are vital in minimizing pathogenic contamination and act as the final barrier against foodborne illnesses.

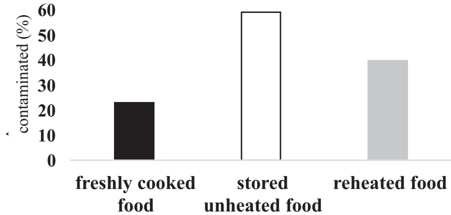

Fig 6: Microbial Contamination in Relation to Food Type
Source: Omemu, *et al.,* 2011

2.5 Studies On Hazard Analysis and Critical Control Points (HACCP)

The Hazard Analysis and Critical Control Points (HACCP) approach determines quickly and relatively cheaply while taking into account local habits and culture, the points in food processes that are critical to safety,

2.5.1 HACCP in small-scale ogi processing centers in Abeokuta, Nigeria

To take advantage of the benefits that fermentation offers, and at the same time minimize its risks, *Omemu and Adeosun (2010) evaluated the hazards and critical control points of ogi production in small-scale processing centers.*

Results showed that most of the producers have no formal education and they produced the ogi in their compounds which they shared with other families. The water used for processing is obtained from the tap or well and stored in drums. Most producers used commercial milling machines to grind the ogi. Garbage disposal and animal rearing around processing sites were noted. Critical control points identified were raw materials, steeping, and fermentation. *Although no coliform was isolated from the maize grains used by all the producers, however, coliform counts were observed in some ready-to-sell ogi* suggesting likely contamination from processors, water and utensils used in processing, and environmental factors.The factors contributing to the

contamination of *ogi* include dirty environment, poor quality of water, and lack of formal education by processors (Table 14, 15). *All the processors surveyed admitted that taps often go dry for several months and that they rely on water from uncovered wells around when this happens.*
The results of this study emphasized the challenge of introducing Good Manufacturing Practices (GMP) and HACCP to traditional processors due to low education levels and entrenched operational habits.Recommendations included educating processors, promoting good hygiene, ensuring the use of clean water, as well as simplifying HACCP to align with traditional practices for effective integration.

Table 14: Process Identification of Hazards for *Ogi* Processing

Process step	Hazard	Source	Control measure
Maize	Chemicals:		
	Mycotoxin	Storage	Supplier Quality Assurance (SQA)
	Physical:		
	Insects , stones	Rural processors	SQA
	Microbiological:		
	Moulds	Storage	Good hygienic practise (GHP); SQA
Steeping/ soaking	Vegetative pathogens Stones	Food handlers, environment,	Good manufacturing practises (GMP)
	Heavy metals	Water by processors	GHP/GMP
Washing	Heavy metals	Water by processors	GMP
	Vegetative pathogens	handlers	GHP, GMP
Wet milling	Filth, dirt and foreign matter.	Milling equipment, environment,	GHP, GMP
	Vegetative pathogens	Water	
Sieving	Vegetative pathogens	Water/equipment, handlers	GMP
Packaging	Vegetative pathogens	Packaging material, Handlers	GHP, GMP

Source: Omemu and Adeosun, 2010.

Table 15: Summary of The HACCP Control Charts of *Ogi* Production

Process step	Hazard	Control measure	Critical limits	Monitoring procedure	Corrective action
Soaking	Growth and contamination by pathogenic and spoilage organisms	Use of clean water, timing of steeping, cleaning of utensils	Portable water Clean utensils	Sensory observation, Inspection of utensils	Educate the processor
Fermentation	Survival of acid tolerant pathogens	pH control, proper timing, use of clean utensils	pH 3.6 – 3.9, Good hygiene.	pH, sensory and visual inspection	Educate the processor

Source: Omemu and Adeosun, 2010.

2.5.2 Hazard identification during processing of Donkwa –an indigenous street vended snack

Donkwa is a popular street-vended snack, made from a mixture of roasted-ground peanut and maize, sometimes with added pepper, and shaped into small forms in Nigeria. Despite its widespread consumption, particularly among school children, information on the quality and safety of *donkwa* is limited. Hence, Ojo, Obadina, Sobukola, Omemu and Adekoya(2017) assess the safety of street-vended *donkwa* through analysis of physical, chemical, and microbiological hazards. Hazard analysis was also conducted to identify potential hazards associated with *donkwa* at various stages of processing. The processing operations of *donkwa* were observed and samples were collected at various stages of processing. Control samples were prepared in the laboratory.

Results show that physical contaminants detected in the samples during processing included sand, animal hair, and extraneous vegetable matter (EVM) which suggests potential rodent contact during storage or drying, possibly due to poor storage facilities. Some processors used sand for roasting, increasing the risk of sand or pebble contamination. The street-vended *donkwa* samples were also contaminated with fungi, *Staphylococcus spp*., and *Bacillus* spp. Additionally, lead, arsenic, and cadmium levels exceeded permissible levels stipulated by CODEX (Tables 16 and 17).

The study highlights the lack of control over physical, chemical, and microbiological hazards in street-vended *donkwa* processing centres, emphasizing the need for intervention strategies such as training on Good Manufacturing Practices and Good Hygienic Practices to mitigate these hazards.

Table 16: Levels of Heavy Metals and Microbial Counts of Street Vended *Donkwa*

Vendors	Cadbium (mg/kg)	Lead (mg/kg)	Arsenic (mg/kg)	TFC (10^3 Cfu/g)	*Staphylococcal* spp count(10^4 Cfu/g)	*Bacillus* spp count (10^3 Cfu/g)
1	0.75 ± 0.13^{ab}	ND	0.22 ± 0.09^{b}	1.03 ± 0.52^{c}	2.50 ± 0.53^{a}	1.25 ± 0.47^{c}
2	0.20 ± 0.06^{b}	ND	11.05 ± 3.68^{a}	1.10 ± 0.65^{c}	1.00 ± 0.13^{b}	1.50 ± 0.29^{c}
3	1.02 ± 0.10^{a}	ND	0.18 ± 0.04^{b}	7.00 ± 3.00^{a}	0.50 ± 0.11^{c}	0.25 ± 0.09^{d}
4	0.08 ± 0.07^{b}	ND	ND	3.67 ± 2.08^{b}	1.00 ± 0.22^{b}	5.25 ± 1.24^{a}
5	0.25 ± 0.09^{b}	ND	0.43 ± 0.09^{b}	6.67 ± 2.03^{a}	1.00 ± 0.15^{b}	4.75 ± 0.35^{a}
6	0.12 ± 0.03^{b}	0.03 ± 0.00^{a}	0.83 ± 0.11^{b}	8.00 ± 3.46^{a}	0.75 ± 0.21^{c}	1.25 ± 0.56^{c}
7	0.20 ± 0.05^{b}	ND	0.35 ± 0.02^{b}	4.67 ± 1.03^{b}	0.75 ± 0.53^{c}	1.25 ± 0.16^{c}
8	0.12 ± 0.04^{b}	ND	0.12 ± 0.05^{b}	2.67 ± 0.06^{c}	0.75 ± 0.45^{c}	2.75 ± 0.45^{b}

[1]Means on the same column with different superscripts are significantly different at $p<0.05$. [2]TFC: Total fungal count. [3]ND: Not detected

Source: Ojo *et al.,* 2017

Table 17: Hazard Analysis of *Donkwa* Processing

Process steps	**Contaminants**	**Sources**	**Control measures**
Harvesting/storing of maize and peanut	Chemical Pesticide residues Heavy metals Microbial Microorganisms	Soil	GAP
Roasting of peanut and maize	Chemical Heavy metals Microbial Vegetative pathogens e.g *S. aureus* Physical Stone/sand	Processors Handlers Roasting technique	GMP

Milling	Chemical Heavy metals Microbial Microorganisms	Equipment Environment Processors	GHP GMP
Moulding	Chemical Heavy metals	Processors Environment	GHP GMP
Packaging	Microbial Microorganisms	Processors Handlers Packaging Materials	GHP

[1]Hazard Category. [2]GAP: Good Agricultural Practices. [3]GMP: Good Manufacturing Practices. [4]GHP: Good Hygienic Practices

Source: Ojo *et al.,* 2017

2.5.3 Microbiological hazard and critical control point identification during household preparation of cooked food

The introduction of solid foods during infant weaning often leads to increased diarrheal episodes due to contaminated weaning foods. Homemade foods are preferred by many mothers under the belief that they are pathogen-free, but research suggests otherwise. Omemu and Omeike (2010) focused on the identification of microbiological hazards and critical control points during household preparation of cooked ogi, as well as document practices that might contribute to contamination.

Our findings showed that condiments like powdered milk, sugar, crayfish, peanuts, and raw eggs are commonly added to ogi, to improve the nutritional content but these acts also introduce hazards especially when they are added after heat treatment. Observation revealed an increase in microbial counts after the addition of condiments and prolonged storage (> 6 hours). The Critical Control points identified include purchasing raw ogi from street vendors, adding ingredients after heat application, and extended storage at ambient temperature (> 4 hours). The study emphasizes the importance of incorporating food safety education into primary healthcare initiatives for mothers to ensure infant nutrition and well-being.

3.0 HUMAN CAPACITY BUILDING AND UNIVERSITY SERVICES

Capacity building encompasses a range of activities, including training, education, mentorship, and organizational development, aimed at empowering individuals and institutions to achieve their full potential. Throughout my career journey at FUNAAB, I have had the privilege of both receiving and imparting knowledge. This journey of nurturing growth and development in others has been both enriching and transformative, and I am grateful for the chance to make a meaningful impact in the lives of students, colleagues, and the wider academic community.

3.1 Research Supervision: Cultivating Future Leaders

Research supervision stands as a cornerstone of my capacity-building efforts. Over the last 28 years, I have supervised more than 180 undergraduate students, many of whom have gone on to excel in their respective fields. Additionally, I have supervised 15 M.Sc. and 3 Ph.D. students as a major supervisor, and served as a co-supervisor for several others, contributing significantly to their research success.

3.2 Mentorship and Professional Development: Fostering Leadership

Mentorship can be formal or informal. Mentorship and professional development are integral to my commitment to capacity building. I was fortunate to be selected as a recipient of the prestigious two-year Post-doctoral fellowship of the African Women in Agricultural Research and Development (AWARD) from 2010 to 2012. This fellowship provided invaluable support to women scientists, enhancing their leadership skills and promoting their contributions to agricultural development in Africa. During this program, I served as a formal mentor to Ms. Bidemi Egbotan (now Dr. Mrs. Bidemi Ojo) after her B.Sc., today she flourishes as a lecturer in the same department, showcasing the lasting impact of effective mentorship. Later, under the AWARD program but with focus on gender inclusivity (AWARD-FUNAAB), I was assigned as a mentor to Engineer Babatunde Oteshile, also a staff member of FUNAAB. In addition, I had the privilege of formally mentoring Dr. Lateefat Oyinlola under the My Community, Our Earth (MyCOE) SERVIR Global Fellowship initiatives in West Africa from 2013 to 2014 during her M.Sc program. Lateefat's exceptional work, nurtured through mentorship, led to her selection by USAID and NASA to present her M.Sc. research at a featured session in Florida, USA, in April 2014. She has since completed her Ph.D. and is presently a Lecturer at Osun State University.

I have had the privilege of informally mentoring several other mentees, some of whom are present here today. These mentees have become distinguished scholars and practitioners in various locations across the nation and around the world.

3.3 Training: Equipping Stakeholders for Food Safety

In training, I served as the Nigeria Program Assistant Coordinator for two vital West African capacity-building programs namely Food Safety for Nutritionists and Other Health Professionals (FSN), and Short course on Hazard Analysis and Critical Control Points. These programs which ran annually from 2014 to 2018, were jointly organized in partnership with the International Life Sciences Institute (ILSI), the Food Safety Training Centre at the University of Ghana, and FUNAAB. The initiatives were generously funded by ILSI, a nonprofit organization dedicated to advancing food safety education and training across the Sub-Saharan African Region. Through these programs, we trained over 150 food handlers, food scientific officers from eleven local governments in Ogun state, caterers, and small business owners, equipping them with essential food safety practices and risk mitigation strategies.

Building upon this experience, I also served as a facilitator for the Ogun State Homegrown School Feeding Program, providing training for food vendors across the state on hygiene standards, safe food handling practices, and ensuring food safety throughout the entire food chain.
My commitment to capacity building extends beyond individual contributions. I actively fostered collaboration across institutions and sectors. I remain dedicated to nurturing future generations of food safety professionals and researchers. By working collaboratively, we can ensure a future where everyone has access to safe and nutritious food.

3.4 University Services
I started my career in FUNAAB in 1995 as a Graduate Assistant and I rose through the rank to become a professor. In between this journey, the system provided me with opportunities to learn, grow and serve. I have had the privilege to serve the University as Ag. Head, Department of Food Service and Tourism (2012-2013), Ag. Head, Department of Hospitality and Tourism (2013-2016), Deputy Dean, Post graduate School (2017-2019, First female), Chairperson, Board of FUNAAB Guest House (2018-2022), Member, University Ceremonial Committee (2018-2020), Dean, Student Affairs (2020-2023, First female), Member- Appointment and Promotions Committee for Academic Staff (APCAS) (2023 till date), Dean, College of Food Science and Human Ecology (January 2024 till date), member of University Senate (2012 till Date) and member of several other University committees.

The Bible says in Eccl 9 verse 11: …..the race is not to the swift, Nor the battle to the strong, …….. But time and chance happen to them all. (NKJV). Also Romans 9: 16 (NKJV) says So then it is not of him who wills, nor of him who runs, but of God who shows mercy. Therefore, in all these, I conclude that God has been so kind and good to me and I give glory to Him for His mercies.

4.0. CONCLUSION

Food Safety: A Shared Journey from Farm to Fork

Food safety is not a destination, it is a journey – a journey where everyone involved, from farm-to-fork, plays a crucial role. It is not a solo act; it is a collaborative effort that requires a shared responsibility from everyone involved in the food journey, from farm to fork. While governments and food industries play a critical role, scientists, educators, media outlets, and even consumers all contribute to a safe and healthy food system. Imagine a relay race where the baton, representing safe food, is passed from one participant to the next. A weak link or fumble disrupts the entire race, just like a lapse in food safety at any stage can lead to contamination and illness. By working together, each stakeholder strengthens the chain of food safety.

From agriculture to consumption, we navigate a dance between beneficial and harmful microbes, emphasizing the need for responsible stewardship of human intervention through diligent practices, robust regulations (HACCP, GAP, GHP), and consumer awareness that safeguards our food journey. Although diligent farm practices, rigorous protocols, and HACCP implementation create a strong foundation, vulnerabilities remain, reminding us of the constant need for vigilance. It is at this intersection of microbial influence and human action that our collective responsibility takes the center stage. Let us reaffirm our commitment to fostering a culture of food safety that transcends borders and cultures. By embracing a holistic approach that encompasses science, education, and collaboration, we are empowered to navigate the farm-to-fork journey with confidence and resilience. This ensures that every meal served from farm-to-fork is not only a source of nourishment but also a testament to our unwavering dedication to public health and well-being.

5.0 RECOMMENDATIONS

To achieve a truly safe food system, here are specific recommendations for key stakeholders:

i. The Governments and Policymakers should set the rules of the game by establishing food safety regulations and enforcing them through inspections and penalties. They can fund research on food safety issues and invest in training programs for food industry personnel and consumers. Additionally, promoting sustainable practices in agriculture and fostering collaboration between public health, animal health, and agriculture are crucial steps to achieve a truly safe food system.

ii. Authorities, and local authorities in particular, should consider informal agents as partners in local development initiatives. They should implement policies and programmes aimed at creating adequate conditions for informal sector activities to be efficiently undertaken while minimising risks to society.

iii. Government and policymakers can leverage advancements in technology such as blockchain, IoT sensors, and data analytics to enhance traceability across the supply chain. This transparency fosters accountability and facilitates swift response in case of contamination or outbreaks

iv. The role of farmers starts at the very beginning by adopting Good Agricultural Practices (GAP). Farmers can minimize contamination risks at the source by responsibly managing pesticides, animal waste, and irrigation water.

v. The Food Industry consisting ofProducers, processors, and retailers has the responsibility to implement food safety management systems like HACCP, Good Manufacturing Practises (GMP), or GAP. They must maintain hygiene standards, allergen controls, and ongoing monitoring programs.

vi. The Media as watchdogs and communicators plays a vital role in raising public awareness about safe food handling practices including proper food labeling. They can achieve this by creating engaging content that educates the public about food safety, utilizing diverse platforms to ensure this information reaches everyone. Media outlets can use creative tools such as cartoons to convey essential messages, as well as address issues on TV and local radio to make the information available in local dialects and across several platforms.

vii. Scientific and Educational Institutions should help identify and address emerging food safety threats through their various researches. Institutions can facilitate community engagement and outreach efforts to empower consumers with knowledge and skills to make informed decisions about food safety. They can also organize workshops, seminars, and public awareness campaigns to raise awareness about safe food handling practices and risk mitigation strategies.

viii. International Collaboration:Government and scientific institutions can foster international collaboration and knowledge-sharing initiatives to address global challenges related to food safety. Support initiatives such as the World Health Organization's International Food Safety Authorities Network (INFOSAN) to facilitate communication and cooperation among food safety authorities worldwide.

ix. Consumers can play a vital role by making informed choices based on food labels, practicing safe food handling techniques at home, and reporting any suspected foodborne illnesses.

By implementing these recommendations, we can work towards ensuring the safe and secure journey of food from farm to fork, protecting public health and fostering consumer confidence in the food we eat.

6.0 ACKNOWLEDGEMENTS

I would like to begin by expressing my deepest gratitude, particularly to God. Throughout the intricate journey of my career, I have encountered numerous challenges and opportunities. I am eternally grateful for God's guiding hand, which has helped me

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I express my heartfelt gratitude to my parents, Prince Adegbenga Alabi and Mrs. Olabisi Adesemowo, for their unwavering support, care, and prayers. Their encouragement and belief in my potential have been the bedrock of my achievements. I am deeply indebted to them for instilling in me the values of perseverance and dedication which have propelled me to this momentous occasion. Thank you, Sir and Ma.

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I extend my gratitude to FUNAAB as an institution and all the key actors in FUNAAB for providing me with an exceptional platform to flourish and achieve numerous milestones in my academic and professional journey. I am immensely proud to have been the first M.Sc. student ever produced by FUNAAB, a distinction that laid the foundation for many other 'firsts' in my life. I am eternally grateful to FUNAAB for nurturing my talents and providing me with the platform to make a meaningful impact.

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Mr. Vice-Chancellor Sir, permit me to make special mention of Prof. Olusola B. Oyewole, during whose tenure I became a Professor in 2015. Professor Oyewole's mentorship and guidance have been invaluable to me. He was my “run-to” lecturer while I was on my undergraduate project at OSU (Now OOU), he later encouraged me to pursue my Master's degree at FUNAAB, and his support throughout my M.Sc. and Ph.D. programs is invaluable.

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Mr. Vice Chancellor Sir, I want to appreciate the immediate past Vice Chancellor, Prof. Felix Kolawole Salako. I am indebted to Prof. Salako for considering me fit to serve as the first female Dean of Student Affairs and for giving me all the support I needed to function during my tenure. His confidence in my abilities brought out virtues in me that I never knew I possessed, and I am honoured to have served in that capacity under his leadership. God bless you, Sir. Lastly, I express my gratitude to the current Vice-Chancellor, Prof. Babatunde Kehinde, under whom I am serving as the Dean of a college (COLFHEC). I thank you also for granting me the opportunity to have this inaugural lecture today.

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