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FOOD ON THE TABLE: THE MICROBIAL CONTRIBUTIONS

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The Vice Chancellor, Sir,
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My Lords Spiritual and Temporal,
Friends of the University/Special Guests,
Erudite Academics,
Distinguished Ladies and Gentlemen,
Gentlemen of the Press,
Students of Federal University of Agriculture, Abeokuta

1.0 PROLOGUE

In the beginning, God created the heavens and the earth, including day and night, the elements (sun, moon, stars, soil and water), living and non-living things. The living things include man, animals, plants and microorganisms, with man having dominion over all things created on the earth (Gen 1:1-31, New International Version).

God created these living things to grow and multiply on the face of the earth. In most living things, growth refers to changes in an individual organism but in micro-organisms, growth usually refers to multiplication of cells i.e. increase in the number of the cell through reproduction.

Microorganisms therefore, on alighting on a suitable food medium will grow and multiply on the food to either spoil it or convert the food to other products which may be useful or useless or even pathogenic to man when consumed. Man since existence had always observed these activities on food but never attributed it to micro-organisms but to chances, witchcraft and gods who wanted to destroy or bless.

Micro-organisms are living organisms too small to be seen with the naked eyes. The presence and roles of micro-organisms to life were unknown until the era of the knowledge of microbiology which began when people made lenses from pieces of glass. These lenses were combined to give magnifications great enough to see micro-organisms observed to be present everywhere except in sterile and inert materials and places, carrying out what they know how to do best which is the perpetuation of their lives. This activity has made them to be either micro friends or micro enemies.

2.0 INTRODUCTION

2.1 History of Microorganisms in Food

In the beginning, man was a food gatherer but later became a food producer. The food gathering period covered the time from man's origin over 1million years ago and man was presumably carnivorous in his eating habits. Plant foods came into his diet later in this period and man learned to cook his foods (Jay, 1978). The food producing periods dates from about 8,000 to 10,000 years ago to the present time. It is presumed that man first encountered the problems of food spoilage and food poisoning early in this period (challenge of food poisoning). The problems of disease transmission through foods and faster spoilage of prepared foods due to improper storage became noticeable and dated from around 6,000 BC.

The practice of making pottery, said to have originated from the Near East but brought to Western Europe around 5,000 BC encouraged cooking, brewing, and storage of foods with mold boiler pots. The first manufacture of beer has been traced to ancient Babylonia possibly dating as far back as 5,000 to 9,000 BC while the Sumarians of about 3,000 BC are thought to be the first great livestock breeders and dairy men, and among the first to make butter. They also fed on salted meats, fish, fats, dried skins, wheat, barley etc. The Egyptians, as early as 3,000 BC fed on milk, beer and cheese, while the Jews between 3,000 and 1,200 BC employed salt from the

Dead Sea in the preservation of various foods. The Chinese and the Greeks around this same time also had salted fish in their diet and were credited with passing this practice to the Romans who later included pickled meats in their diets.

All these periods which could be regarded as the pre-scientific era, preceded the establishment of bacteriology or microbiology as a field of study. Man probably did not understand the nature of these preservation techniques. Food spoilage and food poisoning were not associated with microorganisms. Ergot poisoning caused by toxin in a fungus (*Claviceps purpurea*) growing on rye and other grains resulted in many deaths in the middle ages. France in 943AD recorded over 40,000 deaths due to ergot poisoning. (Jay 1992)

The role of microorganisms was however unknown in the contribution to food on the table. A monk, called Athanasius Kirchner in 1658 was perhaps the first man to suggest the role of microorganisms in the spoilage of foods. He examined decaying bodies, meat, milk and other substances and discovered what he referred to as "little worms", invisible to the naked eyes. However, his observations did not receive wide acceptance since his descriptions lacked precision. Those "little worms" were later described accurately by Antonie Van Leeuwenhoek in the Netherlands in 1683 and recognized as bacteria.

Foods and food materials were observed to be unacceptable for consumption after some time on the shelf due to unknown reasons. Then, the theory of spontaneous generation – that microorganisms evolved unprompted - was used to explain this. Lazarro Spallanzani showed that beef broth which had been boiled for an hour and sealed remained sterile and did not spoil in an attempt to disproof the doctrine of spontaneous generation of life. His idea was rejected since his treatment excluded oxygen which was required for life. Theodor Schwann in 1837 heated infusion in the presence of air, which he passed through heated coils and the infusion remained sterile, thus further disproving the idea of spontaneous generation of life.

These treatments demonstrated the concept of heat preservation of foods, though unknown at that time. In 1795, the French government offered a prize of Fr 12,000 for the discovery of a practical method of food preservation. François (Nicholas) Appert , succeeded in preserving meats in glass bottles that had been kept in boiling water for varying periods of time and Appert was granted a patent for it in 1810. The principle behind this form of preservation was unknown even to Appert, as the knowledge of microorganisms and microbial activities was vague at that time. The precise role of microorganisms in food was not discovered until 1837 when Louis

Pasteur showed that souring of milk was caused by them.

Some significant dates and events in the history of food spoilage, food poisoning and food preservation are listed below.

Food Spoilage

1659- Kircher demonstrated the occurrence of bacteria in milk; Bondeau did the same in 1847.
1780- Scheele identified lactic acid as the principal acid in sour milk.
1876- Tyndall observed that bacteria in decomposing substances were always traceable to air, substances, or containers.
1902- The term *psychrophile* was first used by Schmidt-Nielsen for microorganisms that grow at 0°C.
1912- The term *osmophile* was coined by Richter to describe yeast that grows well in an environment of high osmotic pressure.
1915- *Bacillus coagulans* was first isolated from coagulated milk by B.W. Hammer.

Food Poisoning

1820- The German poet Justinus Kerner described "sausage poisoning" (which in all probability was botulism) and its high fatality rate.
1857- Milk was incriminated as a transmitter of typhoid fever

by W. Taylor of Penrith, England.

1888- Gaertner first isolated *Samonella enteritidis* from meat that had caused 57 cases of food poisoning.

1894- T. Denys was the first to associate staphylococci with food poisoning.

1896- Van Ermengem first discovered *Clostridium botulinum*.

1906- *Bacillus cereus* food poisoning was recognized. The first case of diphyllobothriasis was recognized.

1937- Paralytic shellfish poisoning was recognized.

Food Preservation

1782- Canning of vinegar was introduced by a Swedish chemist.

1810- Preservation of food by canning was patented by Appert in France.

- Peter Durand was issued a British patent to preserve food in "glass, pottery, tin, or other metals, or fit materials". The patent was later acquired by Hall, Gamble, and Donkin, possibly from Appert.

1835- A patent was granted to Newton in England for making condensed milk

1839- Tin cans came into wide use in the United States.

- L.A. Fastier was given a French patent for the use of brine bath to raise the boiling temperature of water.

1840- Fish and fruit were first canned.

1841- S. Goldner and J. Wertheimer were issued British pat-

ents for brine baths based on Fastier's method.

1842- A patent was issued to H. Benjamin in England for freezing foods by immersion in an ice and salt brine.

1843- Sterilization by steam was first attempted by I. Winslow in Maine.

1854- Pasteur began wine investigations. Heating to remove undesirable organisms was introduced commercially in 1867-1868.

1855- Grimwade in England was the first to produce powdered milk.

1865- The artificial freezing of fish on a commercial scale was begun in the United States, Eggs
followed in 1889.

1874- The first extensive use of ice in transporting meat at sea was begun.

- Steam pressure cookers or retorts were introduced.

1907- E. Metchnikoff and co-workers isolated and named one of the yogurt bacteria, *Lactobacillus delbrueckii subsp. bulgaricus.*

- The role of acetic acid bacteria in cider production was noted by B.T.P. Barker.

1950- The D value concept came into general use.

1955- Sorbic acid was approved for use as a food preservative.

- The antibiotic chlortetracycline was approved for use in fresh poultry (Oxytetracycline followed a year later). Approval was rescinded in 1966.

1988- Nisin was accorded GRAS (generally regarded as safe) status in the United States.
1997- Ozone was declared GRAS by the U.S. Food and Drug Administration for food use.

2.2 Microorganisms

Microorganisms are living things that cannot be seen with the ordinary eyes but with the help of magnifying instruments called microscopes. These microorganisms are often grouped into:

1. Bacteria
2. Yeasts
3. Moulds

There is another distinct group called Viruses, however, there are debates from several angles whether they should be classified as microorganisms or not.

Bacteria

Bacteria are microscopic organisms whose single cell have neither a membrane-enclosed nucleus nor other membrane-enclosed organelles like mitochondria and chloroplasts. They reproduce by binary fission.

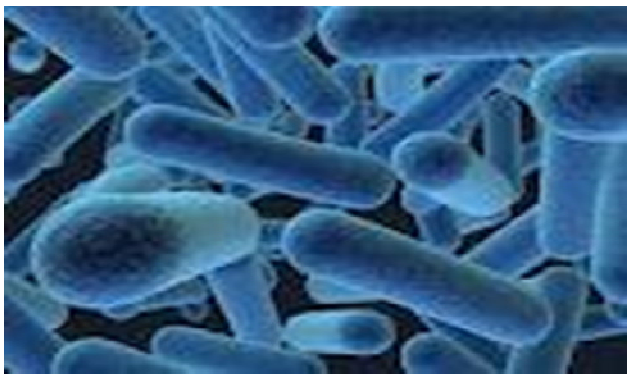

Plate 1: Bacterial cell as seen under scanning electron Microscope
Source: Miloslav *et al.*, 2008

Yeasts

Yeasts are single-celled fungi. The typical yeast cell is approximately equal in size to a human red blood cell and is spherical to ellipsoidal in shape. Yeast reproduces vegetatively by budding.

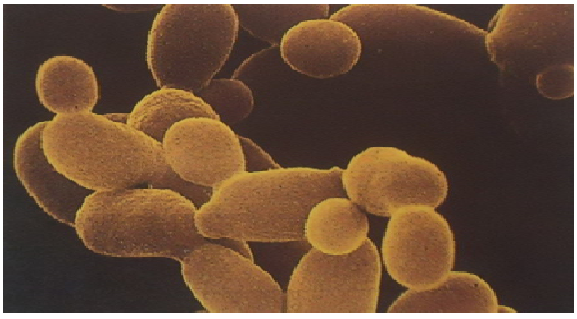

Plate 2: Yeast cells as seen under scanning electron microscope

Source: Willey *et al*., 2008

Moulds

They are filamentous, multicellular microorganisms. Their long filaments of fused cells called hyphae. These hyphae grow into their food source to form a network called mycelium. Moulds produce spores for reproduction and these spores are spread through air, water, or by insects.

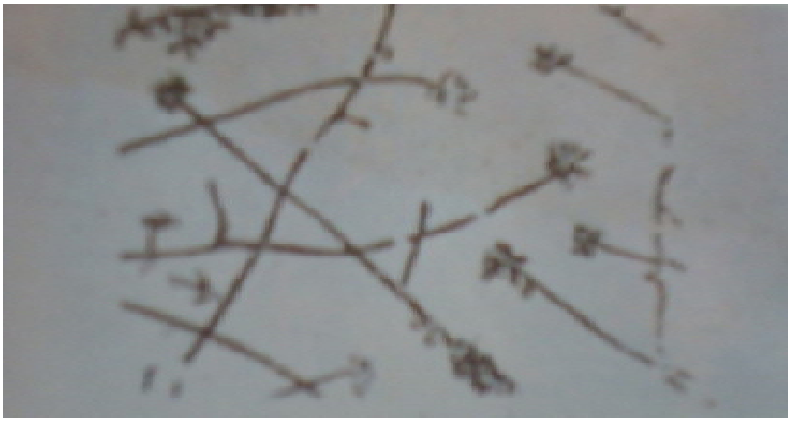

Plate 3: Hyphae of mold (*Neurospora crassa*) viewed in a frozen-hydrated state with a cryo-scanning electron microscope

Source: Pyatkin and Krivoshein (1987)

Microorganisms are present everywhere carrying out what they know best – **the perpetuation of their lives**. In doing this they carry out activities which may be detrimental or com-

plimentary to nature, especially man. In food, their activities may be destructive (taking food off the table) or constructive (bringing food to the table).

This lecture will highlight food situation in the world, contributors to the availability of food, what roles microorganisms play in food production, from farm to fork (the table). The nexus between microorganisms' struggle for perpetuity and how that influences food availability will be x-rayed while the strategies employed by man to overcome microbe's detrimental effects are highlighted.

3.0 SOURCES OF FOOD

According to the Encyclopaedia Britannica (2011), food is any material consisting essentially of protein, carbohydrate, and fat used in the body of an organism to sustain growth, repair, carry out vital processes and to furnish energy. Also, food is described as any substance consumed to provide nutritional support for the body. It is usually of plant or animal origin, and contains essential nutrients, such as carbohydrates, fats, proteins, vitamins, or minerals. The substance is ingested by an organism and assimilated by the organism's cells in an effort to produce energy, maintain life, or stimulate growth.

Though initially food has been used as mainly a source of en-

ergy, today it has also assumed a sensory, cultural and social dimension. In addition to satisfaction, food is now desired to promote our health and well-being. Based on prevailing economic and work schedules, many do not have the time or are not willing to spend this scarce resource in preparing elaborate meals. Food has to be quick and convenient to prepare, as well as healthy and tasty. Lifestyles and work status have affected the dietary behaviours of man over the years (Table 1).

Table 1: Lifestyle and Food (Nutrient) Consumption

Lifestyle	Fat	Sugar	Starch	Protein	Fibre (g/day)
Hunter-gatherers	15-20	0	50-70	15-20	40
Peasant Farmers	10-15	5	60-75	10-15	90
Affluent Societies	40+	20	25-30	12	20

Source: Klaus-Dieter (2000)

Even if the obvious is to be disregarded, meeting the food needs of the world especially among the almost 170 million Nigerians (Nigerian demographic population study, July, 2012) is no easy task and is becoming more difficult. Furthermore, as the population grows and the number of farmers decline, there is increasingly pressure on transport and storage systems. It may therefore seem impossible to meet all the demands. However, technological progress in food manufacturing and

recent discoveries in nutritional science has resulted in increasingly high food quality standards and enormous food variety (EUFIC REVIEW, 2000)

Almost all foods are of plant or animal origin. Cereal grain is a staple food that provides more food energy worldwide than any other type of crop. Maize, wheat, and rice - in all of their varieties - account for 87% of all grain production worldwide.

a. Plants

There are around 2,000 plant species which are cultivated for food, and many have several distinct cultivars. Many plants or plant parts are eaten as food such as seeds, fruits and vegetables.

Seeds of plants are a good source of food for animals, including humans, because they contain the nutrients necessary for the plant's initial growth, including many healthy fats, such as Omega fats. In fact, the majority of plant-based foods consumed by human beings are seed-based foods. Edible seeds include cereals (maize, wheat, rice, oat, and barley), legumes (beans, peas) and nuts. Oilseeds are often pressed to produce rich oils - sunflower, flaxseed, rapeseed (including canola oil), sesame etc.

b. Animals

Animals are used as food either directly or indirectly by the products they produce. Meat is an example of a direct product taken from an animal, which comes from muscle systems or from organs. Food products produced by animals include milk produced by mammary glands, which in many cultures and countries is drunk or processed traditionally into dairy products such as yoghurt, cheese and butter.

In addition, birds and other animals lay eggs, which are often eaten, and bees produce honey, a reduced nectar from flowers, which is a popular sweetener. Some indigenous cultures consume blood, sometimes in the form of blood sausage, as a thickener for sauces, or in a cured, salted form for times of food scarcity, and others use blood in stews such as civet.

Some cultures and people do not consume meat or animal food products for cultural, dietary, health, ethical, or ideological reasons. Vegetarians do not consume meat. Vegans do not consume any foods that are or contain ingredients from an animal source (Encyclopaedia Britannica 2001).

4.0 ROLES OF MICROORGANISMS IN FOOD PRODUCTION

Microorganisms are helpful in the following ways:-

1. In soil: They are essential to the cycling of nutrients in the

ecosystems of the planet. e.g. Nitrogen, Phosphorus, Sulphur and Water Cycles
2. In plants: Photosynthesis, Mycorrhiza
3. Fermentation: Enzymes
4. Probiotics

4.1 Detrimental Effects of Microbes in Food

Foods may be contaminated by microorganisms at any time during harvest, storage, processing, distribution, handling, or preparation. The primary sources of microbial contamination are soil, air, animal feed, animal hides and intestines, plant surfaces, sewage, and food processing machinery or utensils.
Food contamination may lead to:

1. Food poisoning and Food-borne illnesses: Food poisoning is defined as an illness caused by the consumption of food or water contaminated with bacteria and/or their toxins, or with parasites, viruses or chemicals. The symptoms vary from mild cases such as abdominal pain, vomiting, diarrhoea, and headache, while the cases can result in life-threatening syndromes leading to permanent disability or death. Most food borne illnesses are mild and improve without any specific medication (Table 2).

   Foodborne illness is not a simple problem in need of a

solution; it is a complex combination of factors that must be managed on a continual basis. A number of factors will drive the emergence of new food safety concerns, including changes in the characteristics of the consuming public, changes in the foods we manufacture and sell, changes in the hazards themselves, and changes in the ability of public health officials to identify illnesses as foodborne and to trace the illnesses to their food source.

Table 2: Common food poisoning organisms and their epidemiology

Name of bacterium	Original source	Risky foods	Time to develop	Symptoms	Treatment
Bacillus cereus	A soil organism	cooked rice and pasta; meat products; vegetables	1–5 hours	Causes nausea, abdominal cramp, and diarrhoea	Oral rehydration, intravenous fluids/electrolyte replacement
Campylobacter jejuni	raw meat and poultry	undercooked meat and poultry; raw milk and cross-contaminated food	3–5 days of eating infected food	fever, severe pain and diarrhoea	Rehydration, Antibiotics
Clostridium botulinum (very rare)	soil	faulty processed canned meat and vegetables; cured meat and raw fish	1–7 days	Nausea, vomiting, double vision, paralysis and can be fatal	Antitoxin
Clostridium perfringens	the environment	large joints of meat; reheated gravies	8-24 hours	nausea, pain and diarrhoea	Intraavenous fluids,
Escherichia coli E.coli O157: H7 is a very nasty strain it can be fatal	the gut of all humans and animals	contaminated water, milk, inadequately cooked meat, cross-contaminated foods	3-4 days	inflammation, sickness and diarrhoea	Rehydration, proper nutrition,
Listeria monocytogenes	everywhere	soft cheeses, paté, pre-packed salad; cook-chill products	varies	fever, headache, septicaemia and meningitis	Antibiotics
Salmonella	gut of birds and mammals including humans - spread by faeces into water and food	poultry, eggs and raw egg products, vegetables	6-48 hours	diarrhoea, sickness and headaches	Rehydration, Antibiotics,
Staphylococcus aureus	the skin and noses of animals and humans	cured meat; milk products; unrefrigerated, handled foods	2-6 hours	sickness, pain and sometimes diarrhoea	

Source: Liang, (2002)

2. Food spoilage: Food spoilage is the deterioration of food until it becomes the point where it is unappetizing or unsuitable for human consumption. Food spoilage means the original nutritional value, texture, flavour of the food are damaged, the food become harmful to people and unsuitable to eat.

Plate. 4: Blue mould rot in tomato caused by *Penicillium* sp. (also by *Fusarium* sp.)
Source: Eufic review 2000

Plate 5: Blue mould on oranges caused by *Penicillium digitatum*

Source: Eufic review 2000

4.1.3 Food Preservation Strategies

Food preservation reduces the rate at which food decays by slowing down the rate of growth of microbes or eliminating them. It can affect the flavour and texture of the food. Preservation techniques include: refrigeration, freezing, drying, sterilization and pasteurisation.

Food preservation, any of a number of methods by which food is kept from spoilage after harvest or slaughter, such practices date to prehistoric times. Among the oldest methods of preservation are drying, refrigeration, and fermentation.

Modern methods include canning, pasteurization, freezing, irradiation, and the addition of chemicals. Advances in packaging materials have played an important role in modern food preservation.

The most common methods used either to kill or to reduce the growth of microorganisms are the application of heat, the removal of water, the lowering of temperature during storage, the reduction of pH, the control of oxygen and carbon dioxide concentrations, and the removal of the nutrients needed for growth. The use of chemicals as preservatives is strictly regulated by governmental agencies such as the Food and Drug Administration (FDA) in the United States and the Na-

tional Agency of Food and Drug Administration Control (NAFDAC) in Nigeria. Although a chemical may have preservative functions, its safety must be proved before it may be used in food products. To suppress yeast and mould growth in foods, a number of chemical preservatives are permitted. In the United States, the list of such chemicals, known as GRAS (Generally Recognized as Safe), includes compounds such as benzoic acid, sodium benzoate, propionic acid, sorbic acid, and sodium diacetate.

Cooking is a heat treatment, usually performed before the product is placed in the finished product container. It is applied to fishery products that are distributed either refrigerated or frozen. Generally, after cooking, fishery products are referred to as cooked, ready-to-eat. Examples of cooked, ready-to-eat fishery products are crabmeat, lobster meat, crayfish meat, cooked shrimp, surimi-based analog products, seafood salads, seafood soups and sauces, and hot-smoked fish.

Pasteurization is a treatment (usually, but not always, the application of heat) applied to eliminate the most resistant pathogenic bacteria of public health concern that is reasonably likely to be present in the food for as long as the shelf-life of the product, when stored under normal and moderate abuse conditions. With fishery products, pasteurization is usually performed after the product is placed in the hermetically

sealed finished product container. It is applied to fishery products that are distributed either refrigerated or frozen. Examples of pasteurized fishery products are pasteurized crabmeat, pasteurized surimi-based analog products, and pasteurized lobster meat.

In addition to eliminating bacterial pathogens, cooking and pasteurization also greatly reduce the number of spoilage bacteria present in the fishery product. These bacteria normally restrict the growth of pathogens through competition. Elimination of spoilage bacteria allows rapid growth of newly introduced pathogenic bacteria. Pathogenic bacteria that may be introduced after cooking or pasteurization are, therefore, a concern. This is especially true for pasteurization, because that process can significantly extend the shelf-life of the fishery product, providing more time for pathogenic bacteria growth and toxin formation.

Retorting is a heat treatment that eliminates all food-borne pathogens and produces a product that is shelf stable. Mandatory controls for retorting are provided in the Thermally Processed Low-Acid Foods Packaged in Hermetically Sealed Containers.

Unwanted micro-organisms such as *Listeria, Salmonella, Clostridium* or *Escherichia coli* need moisture, neutral pH values, low salt

and sugar concentration and moderate temperatures to grow. Approaches have been undertaken to prevent the growth of these micro-organisms even after mild processing conditions, for example, various combinations of heat and acid treatments, addition of antimicrobials, magnetic field pulses or computer aided design of equipment that is easily cleaned. As heating can destroy sensitive food ingredients, e.g. vitamins, modern pulse heat treatment involves very brief heating interspersed with cooling phases. Another way to combat microbial growth is water extraction, i.e. industrial microwave drying of fruits or spray-drying of milk. Microwave drying offers the advantage of relatively low temperatures combined with the reduction of pre-existing moisture levels resulting in preserving valuable nutrients and flavours.

Air filtration, aseptic packaging and protective atmospheres are used to reduce food spoilage, but freezing still plays a key role. Therefore, current research efforts concentrate on changes of nutrients and texture in foods during cold storage to further optimise freezing processes and product composition. Another recent development is the application of high pressure pasteurisation in fruit and vegetable products. This procedure will increase the shelf life of products while preserving the nutritional content, flavour and colours. Ultra Violet (UV) irradiation of process water is an increasingly used method of disinfection. A recent development is the use of

circular sugar molecules of various sizes with wide application range (cyclodextrins), e.g. to trap and remove certain micro-organisms such as *Listeria* species from foodstuffs. Until food is picked from the market's shelves, modern sensitive detection methods should accompany the production process to ensure high quality food.

4.2 Beneficial Contributions of Microbes in Food

Microorganisms do not always produce unwanted changes in foods but they can transform food materials thereby leading to the production of better desirable foods. Examples:

a. WHOLE CELLS: Consumed directly as foods

i. *Spirulina*: a photosynthetic, filamentous, spiral-shaped, multicellular and green-blue microalga, is used as human food by Mexicans (Aztecs) and the Kanembu people in Chad. Other microalgae consumed by man are *Chlorella, Dunaliella salina.*

ii. Mushrooms are edible macrofungi that are consumed by man. Mushrooms are high in fibre and proteins, rich source of Vitamin B & C, and minerals including Potassium, iron, riboflavin, niacin, selenium (Alofe *et al.,* 1996). Mushrooms generally have less protein than animals but more than most plants. They have all the essential amino acids. They are low in carbohydrates, and sodium while they contain no cholesterol or fat-free. They are high in

antioxidants and help in building a healthy immune system.

b. WHOLE CELLS USED TO TRANSFORM FOOD SUBSTRATES

Over many millennia, mankind has learned how to select edible plant and animal species, and how to produce, harvest and prepare them for food purposes. This was mostly done on the basis of trial and error and from long experience.

One of the most well-known applications of microorganisms in industry is fermentation, where carbohydrates (such as sugar) are converted into an acid or an alcohol. Fermentation is almost as old as history, people having used it to make sourdough, alcoholic beverages, vinegar, yoghurt and cheese as far back as 700 BC. For thousands of years humans have taken advantage of natural fermentations to make alcoholic drinks, bread, dairy products and pickles, although no-one understood that microbes were responsible for these processes until recently. It came of age in the 19th century when Louis Pasteur discovered that it was yeast which converted sugars to ethanol and that bacteria caused spoilage by converting ethanol to acetic acid.

Fermentation not only gives food a good taste, texture and smell, but it causes changes that inhibit the growth of undesirable food microbes, improving its storage life and safety.

Nowadays fermentations are used to make an amazingly wide range of food and drink.

Microbes are involved in the production of foods in other ways too, and without their help, man's diet would be very dull indeed. Microbes break down complex molecules in food to provide the energy for their growth. As by-products they sometimes produce the fermented foods and drinks that we enjoy. It is all in the perpetuation of their lives

i. Milk-based fermented products

Milk fermentation is developed at many places to preserve milk solids and to make novel and tasty foods such as youghurt, soured milk, buttermilk, cheese, kefir, nono, wara e.t.c**.**

ii. Fermented root products

a. Cassava is processed to make: Lafun, Fufu and Gari
b. Yam: Yam Flower "Elubo" is used for the preparation of "Amala", which is an important delicacy in Nigeria and parts of West Africa.

iii. Fermented Cereals / Beverages

- **Ogi**: Ogi porridge is prepared from fermented maize, sorghum or millet.
- **Beer: Barley + Yeasts (***Saccharomyces cerevisiae***)**

⟶ Beer

Beer is made from barley, wheat or rye grain which is germinated to convert starch to sugar such as maltose. The sprouted grain is dried and crushed before hot water and yeast are added to initiate fermentation. In the fermentation process, sugars in the mixture are converted to alcohol and carbon dioxide. After 2–5 days the beer is separated from the yeast, matured and filtered before consumption.

- Bread: Flour (Dough) + (*Saccharomyces cerevisiae*)
⟶ Bread

Lactic acid bacteria work alongside baker's yeast in some doughs to improve the structure, flavour and storage life of French bread and similar products.

- Cocoa Powder:

Cocoa seeds + Microorganisms ⟶ Cocoa Powder

Raw cocoa has an astringent, unpleasant taste and flavour and has to be fermented, dried and roasted to obtain the characteristic cocoa flavour and taste (Thompson *et al.*, 2001). A good flavour in the final cocoa or chocolate is dependent on good fermentation.

iv. Fermented Legumes:

Iru made from locust beans, Ogiri from melon seed and dawadawa

v. Fermented Fruits and Vegetable

Wine from different species of grape

Winemaking, or vinification, is the production of wine, starting with selection of the grapes or other produce and ending with bottling the finished wine. Although most wine is made from grapes, it may also be made from other fruits or non-toxic plant materials.

Winemaking can be divided into two general categories: still wine production (which does not undergo carbonation) and sparkling wine production (which undergoes carbonation).

For wine production, grapes are crushed and undergo two types of fermentations:

i. Primary fermentation (Yeasts): fermentation of sugars into alcohol
ii. Secondary Fermentation (Bacteria): fermentation of malic acid to lactic acid and CO_2 .

For sparkling wines, the carbon dioxide produced by the fermentation process is trapped to create bubbles.

PALM WINE: Sap + Yeasts $\longrightarrow$ Palm wine

Yeasts have been shown to play a major role in the fermenta-

tion of the saps of *Elaeis* guineensis. And *Raphia* sp. Species of *Saccharomyces*, *Candida* and *Endomycopsis* sp were found to be involved in palm-wine fermentation studies in Nigeria by Okafor (1972). *Saccharomyces cerevisiae, Hanseniaspora uvarum, Candida parapsilopsis, Candida fermentati* and *Pichia fermentans* have been found to be involved in the tapping and fermentation of palm wine in Cameroun (Stringini *et al.,* 2009).

vi. Fermented meats: Salami is an Italian fermented pork product that relies on a combination of lactic acid fermentation with curing salts and drying for their keeping quality, safety and colour. Yeasts and moulds may also contribute to the flavour of these products

c. USING ENZYMES SECRETED BY MICROORGANISMS

Enzymes extracted from edible plants and the tissues of food animals, as well as those produced by microorganisms (bacteria, yeasts, and fungi), have been used for centuries in food manufacturing (Table 3). Rennet is an example of a natural enzyme mixture from the stomach of calves or other domestic animals that has been used in cheese making for centuries. Rennet contains a protease enzyme that coagulates milk, causing it to separate into solids (curds) and liquids (whey). It has now been produced in copious quantities by microorganisms. Alternatively, for centuries

enzymes produced by yeast have been used to ferment grape juice in order to make wine.

Though enzymes are formed within living cells, they can continue to function *in vitro* (in the test-tube) and their ability to perform very specific chemical transformations is making them increasingly useful in industrial processes.

In the twentieth century, enzymes began to be isolated from living cells, which led to their large-scale commercial production and wider application in the food industry. Today, microorganisms are the most important source of commercial enzymes. Although microorganisms do not contain the same enzymes as plants or animals, a microorganism can be found to produce a related enzyme that will catalyse the desired reaction (Table 4). Enzyme manufacturers have optimized microorganisms for the production of enzymes through natural selection and classical breeding techniques.

4.3 Genetically Modified Organisms (GMO's) and Food Production

Many potential food ingredients including enzymes, pigments, aromatic and flavour compounds, etc. may be produced by natural or engineered microorganisms. Biotechnology has been applied to change the constituents of food crops.

Table 3: Major Enzymes Used by the Food Industry

Enzyme	Application
Proteases	
Papain, bromelain, ficin	Meat tenderization, haze removal, and chill proofing
Rennin	Cheese making
Glycosidases	
Amylases (alpha-, beta- , gluco-, and debranching)	Baking, brewing, sweetener production
Cellulases/Xylanases	Juice clarification
Glucanases	Brewing
Glucose isomerase	High-fructose corn syrup
Glycolytic enzymes	Fermentation – carbon dioxide and ethanol production
Invertase	Candy making
Lactase (β- galactosidase)	Low-lactose dairy products, whey disposal
Pectinases	Beverage clarification
Lipases	
Acyl glyceride hydrolases and Phospholipases	Texture modification and flavor generation

Source: Wong (1988)

Table 4: Some possibilities for microbial production of actual and partial food ingredients

Enzyme	Application	Producing organisms
Acetic Acid	Acidulant	Acetobacter pastorianus
N-acetyl tripeptide	Immune enhancer	Bacillus cereus
D- arabitol	Sugar	Candida didensii
Beta-carotene	Pigment	Blakeslea trispora
Citric acid	Acidulant	Aspergillus niger
Citronellol	Fruity flavor	Ceratocystis spp.
Diacetyl	Buttery flavor	Leuconostoc cremoris, Streptococcus lactis
Dextrans	Thickeners	Leuconostoc mesenter-oides
Emulsifier	Emulsification	Candida lipolytica
Fatty acid esters	Fruity fragrances	Pseudomonas sp

Source: Wong (1988)

The fact that microorganisms can produce food additives and other useful substances is nothing new. Genetic engineering, however, has opened the door to new possibilities for turning bacteria, yeast, or other fungi into economically viable producers. However, genetically modified microorganisms are useful from a commercial stand-point but would not survive in nature.

GMOs are involved in the following food processes:-

1. Traditionally, rennin used to make cheese, was extracted from frozen calf stomachs. The active ingredient is chymosin, an enzyme produced in the stomach of suckling calves needed for breaking down cow's milk. It is now possible to produce chymosin in genetically modified fungi. These modified microorganisms contain the gene derived from the stomach of calves that is responsible for producing chymosin. When grown in a bioreactor, they release chymosin into the culture medium. Afterwards, the enzyme is extracted and purified yielding a product that is 80 to 90 percent pure. Natural rennin contains only 4 to 8 percent active enzyme. Chymosin produced by genetically engineered microorganisms is now used to produce cheese in many different countries.
2. Beta-carotene colouring (E 160a): used as a yellow dye in butter during the winter - also used in some dairy desserts and yogurt.
3. Riboflavin colouring (E 101: Vitamin B_2); used in cheeses and cream products
4. Preservatives such as Natamycin (E 235), Nisin (E 234), Lysozyme (E 1105); approved for use in cheeses.
5. Dairy desserts, creams, and puddings sometimes contain emulsifiers and thickeners made from GM soybeans or GM maize.
6. Many industrially produced cream products use dried egg

powder instead of fresh eggs. In order to preserve egg powder and maintain its colour, two enzymes are added (lipase and glucose oxidase) that are often produced with the help of genetically modified microorganisms. Dried egg powder can also be found in baked goods, pasta, and noodles.

7. Starch and enzymes:
   The plant starch source (maize and potatoes) can be genetically modified, and the enzymes used for breaking down the starch can be made by genetically modified microorganisms
   Strong acids were once used to break apart starch molecules and release sugar. Now, enzymes do the job offering many advantages: With enzymes, the process targets the proper chemical bonds much more precisely. Different enzymes can be used to produce syrups with different levels of sweetness and different technical characteristics. The end products are not only used as custom tailored ingredients in countless foods and drinks, they can also be further processed into glucose, artificial sweeteners, or fat substitutes.

   For a long time, breaking down starch (saccharification) didn't make economic sense. Things changed, however, as soon as the enzymes responsible for this process became available at low cost, high quality, and at unlimited quanti-

ties. Now, almost all of the enzymes used to break down starch are produced with the help of genetically modified microorganisms.

Presently, most of the enyzmes used in starch saccharification are produced with the help of genetically modified microorganisms. Some of these enzymes are economically impossible to produce without biotechnological methods. Certain procedures use "immobilised" enzymes, which are bound to a reaction surface. Rather than mixing freely, they remain fixed to a surface and are not present in the final product.

8. Baked Goods Production: Though bread is made from conventional flour, other flour additives may also be produced with the help of genetic engineering, for example: ascorbic acid (E300) or cysteine (E921). Many of the enzymes used today (e.g. amylase) are made with the help of genetically modified microorganisms. A few years ago, a genetically modified strain of baker's yeast was tested in Great Britain. This new strain had enhanced carbon dioxide production.
9. Some ingredients used in meat products are obtained from GMOs. Many vitamins, amino acids, and enzymes are produced with the help of genetically modified microorganisms. Ascorbic acid (vitamin C) is used to prevent oxida-

tion, stabilising the colour of sausage. Glutamate is used to enhance flavour. Enzymes (proteases) can make meat more tender and improve aroma. They can also be used to help separate meat residues from bones. Dextrine or maltodextrine (from GM maize) as a filler or stabilizer

10. Alcoholic Beverages

Neither the plants themselves, nor the yeasts used in alcoholic fermentation are genetically modified. Nonetheless, many beverages are produced using enzymes made with the help of genetically modified microorganisms.

Plant materials provide the starch for metabolic fermentation. None of the plants that are used as starch sources for alcoholic beverages have commercially grown genetically modified varieties. The one exception to this is maize, which is sometimes used for brewing beer. None of the yeast strains commercially used in alcoholic fermentation are genetically engineered. However, several research projects were aimed at improving brewing processes to produce low-calorie or low-alcohol beers. Despite several attempts, these efforts have not worked out. These enzymes that drive fermentation naturally occur in raw plant materials or are produced by yeast. Sometimes, however, processes can be

optimised by adding isolates of essential enzymes. Many of these are produced with the help of genetically modified microorganisms.

11. Juices: Enzymes can increase the efficiency of juice extraction by digesting starches and cellulose, a tough compound that is found in plant cell walls. After pressing, fresh juice retains enzymes that break down cloudy, starchy residues. Many of these useful enzymes can now be produced with the help of genetically modified microorganisms. Juices are sometimes fortified with vitamins or sweetened with artificial sweeteners for diabetics. Some of these additives are produced with the help of genetic engineering.

These genetically modified microorganisms play a role in enhancing the safety and quality of our foods, and contribute to further improvement of economical and ecological aspects of food production.

5.0 MY RESEARCH CONTRIBUTIONS

Food consumed by human-beings are rarely sterile as they harbor microorganisms which may originate from the natural microflora of the raw material, and those organisms introduced in the course of harvesting, slaughter, processing, storage and distribution of the food. The number of hungry people in

Nigeria was put at over 53 million which was above one-third of the country's total population of roughly 150 million with 52 percent living under poverty line (Ajayeoba, 2010). Now, Nigeria's population is estimated to be 170.2 million (Nigerian demographic population study, July, 2012). Nigeria was strongly affected by the global food crisis in 2007/2008. Compounding the problems of food production and food insecurity is microbial wastage.

The following will give a brief summary of microbial activities on local foods leading to food and drink wastage and possibly food poisoning:

Makinde (1975) examined some Nigerian local foods sold in four markets around Zaria for their microbial load, types of microorganisms and the possible implications of these microorganisms in these foods (Table 5).

Table 5: The pH, MPN, Microbial load and Microorganisms in four types of consumed food in Zaria

Food	pH	Most Probable Number (MPN Index/ 100ml range)	Microbial Load CFU/gram range	Microorganisms
Fura	5.6	0 – 1800+	4.70×10^5- 9.00×10^9	S. aureus, Pseudomonas aeruginosa, Enterobacter aerogenes, Enterobacter cloacae Proteus vulgaris, K. pneumoniae.
Kulikuli	6.3	0 – 225	3.60×10^5 - 1.15×10^7	S. aureus, Proteus vulgaris, K. pneumoniae, E. cloacae
Tsire	6.4	0 – 1800+	3.90×10^5 - 6.70×10^9	S. aureus, E. cloacae, Proteus vulgaris, E. aerogenes
Kilishi	6.5	0 – 550	1.00×10^5 - 1.10×10^{10}	S. aureus, Proteus vulgaris, Proteus mirabilis, E. aerogenes, E, cloacae, Bacillus species.

Source: Makinde (1975)

These foods are quite cheap and very popular among the indigenous population around Zaria and are prepared by anybody who knows the technique and wants to trade on any of the foods. The pH of the foods were observed to range from slightly acidic: Fura with pH 5.6, while the rest had pH close to neutral depending on the food. These pH ranges thus, are known to generally favour the growth of many types of microorganisms.

The Most Probable Number (MPN) index (which is an indication of possible faecal pollution) and the total viable bacterial count varied, probably due to many factors such as different processors, different conditions of processing, different length of time after production and post-processing exposure and storage.

S. aureus occurred more often than other species. All the *S. aureus* were Mannitol salt and coagulase positive which showed they could be enterotoxin producers hence of food poisoning implication. Although food-poisoning was not reported in this area, there is reason to believe that some of these isolates are enterotoxigenic. Moreover, the nature of staphylococcal food-poisoning is short lived with complete recovery in 24 hours and population attitude to Hospital treatment did not really permit a comprehensive survey of food-poisoning based on Hospital records. Other identified organisms such as *E.*

aerogenes, Ps. aeruginosa, E. cloacae, P. vulgaris, K. pneumonia, Citrobacter, are implicated. There is also some evidence that food containing large numbers of *B. cereus* may cause diarrhea and abdominal pain, though the organism is scarce in the stool of the sufferers (Hauge, 1950).

P. mirabilis, P.vulgaris, K. pneumoniae, Ps. aeruginosa and *E. aerogenes* are known to inhibit enterotoxin production of *S. aureus* when present together (McCoy and Faber, 1966). Since these were isolated along with *S. aureus*, it is likely that they prevent *S. aureus* enterotoxin production and even if produced, the toxin might not be in appreciable quantity.

The major sources of contamination of sampled food were probably man, water and air. The bacterial content of the foods could be decreased if the people are made aware of the presence and harmfulness of these microbes. Processors should be advised to prepare their foods with as little contamination as possible, with clean, healthy hands, and using clean non-contaminated water in a clean area of preparation. Also, the effect of using infected and sick animals as meat in Tsire and Kilishi preparation should be brought to their notice. Hawking around of improperly covered foods and the selling of 3 – 4 days old Tsire and Kilishi should be discouraged.

5.1 'Adoyo'

Microorganisms were also isolated from 'Adoyo' (Bankole, 2005a). An 'acidic' herbal drink used locally for treating many ailments especially malaria. It is also taken to quench thirst particularly when iced. Adoyo is made by boiling pieces of *Enantia chlorantha* (African Yellowwood) with the leaves of *Cymbopogon citratus* (Lemon grass) in 'omidun' the supernatant fluid of processed Ogi) and allowed to cool after which unpealed fruits of Citrus paradise (grape fruits) and *Ananas comosus* (Pineapple) are added, harboured yeast, moulds and bacteria (Table 6). The efficacy of this drink as an antimalarial drug is unknown although some of its materials are medicinal and rich in vitamins. *Cymbopogon citratus* infused in hot water has been known as a diuretic and an anti-malaria drug (Sakeeb, 1997), *Enantia chlorantha* bark is of numerous local medicinal importance including its use as an antipyretic in the curing of fever. It is also used in treating ulcers and tuberculosis (Adegoke *et al*., 1968), *Ananas comosus* (Platt, 1962) *Citrus paradise* (Kosh, 1962) are very rich in vitamins.

All the raw materials for 'Adoyo' preparation are of plant origin and generally contaminated with microorganism from the soil. Omidun, the supernatant solution from processed Ogi is known to harbour yeasts such as *Saccharomyces* sp., *Candida sp., Rodotorula* sp. *Debaryomyces hansenula* and bacteria such as *Lactobacillus* sp. *Corynebacterium* sp. and a number of molds

(Ekundayo, 1985). These raw materials are usually purchased from the market, cut into pieces without prior treatment and 'omidun' added and boiled after which it is left to cool, chilled by adding iced-blocks and offered for sale and consumption. The procedure for processing and distribution for consumption may pre-dispose it to microbial contamination.

Table 6: The pH and the microbial isolates from 'Adoyo'

Sample No	Colour	Consistency	pH	Microbial isolates		
				Bacteria	Yeast	Mold
1	Yellow	Rough, non-homogeneous	3.5 ± 0.1	*Lactobacillus* sp	*Saccharomyces* sp	*Geotrichum* sp *Fusarium* sp
2	Yellow	Rough, non-homogeneous	3.8 ± 0.1	E. *coli*, *Lactobacillus* sp	*Saccharomyces* sp	*Geotrichum* sp *Aspergillus* sp
3	Yellow	Rough, non-homogeneous	3.7 ± 0.1	E. *coli*, *Lactobacillus* sp	*Saccharomyces* sp	*Rhizopus* sp *Aspergillus* sp
4	Yellow	Rough, non-homogeneous	3.75 ± 0.2	E. coli, *Lactobacillus* sp *Micrococus* sp	*Candida* sp Saccharomy-ces sp	*Aspergillus* sp *Fusarium* sp
5	Yellow	Rough, non-homogeneous	4.0 ± 0.0	E. coli, *Lactobacillus* sp S. *faecalis* S. aureus	*Candida* sp	*Rhizopus* sp *Penicillium* sp
6	Yellow	Rough, non-homogeneous	2.6 ± 0.2	S. *faecalis* *Acetobacter* sp	*Candida* sp	*Geotrichum* sp *Penicillium* sp
7	Yellow	Rough, non-homogeneous	2.9 ± 0.1	S. *faecalis* *Lactobacillus* sp		*Aspergillus* sp *Fusarium* sp
8	Yellow	Rough, non-homogeneous	2.8 ± 0.2	*Acetobacter* sp		*Rhizopus* sp *Fusarium* sp
9	Yellow	Rough, non-homogeneous	3.6 ± 0.1	E. *coli*	*Saccharomyces* sp	*Aspergillus* sp *Fusarium* sp
10	Yellow	Rough, non-homogeneous	2.8 ± 0.2	*Leuconostoc* sp *Micrococus* sp	Candida sp	*Botrytis* sp *Alternaria* sp
11	Yellow	Rough, non-homogeneous	3.1 ± 0.1	*Lactobacillus* sp *Bacillus* sp	*Saccharomyces* sp	*Fusarium* sp *Aspergillus* sp
12	Yellow	Rough, non-homogeneous	4.05 ± 0.2	E. *coli* *Acetobacter* sp	*Candida* sp	*Penicillium* sp
13	Yellow	Rough, non-homogeneous	3.9 ± 0.2	E. *coli* *Acetobacter* sp	*Saccharomyces* sp	*Geotrichum* sp *Fusarium* sp
14	Yellow	Rough, non-homogeneous	3.3 ± 0.1	*Leuconostoc* sp *Bacillus* sp	*Candida* sp	*Alternaria* sp *Penicillium* sp
15	Yellow	Rough, non-homogeneous	3.7 ± 0.1	*Micrococus* sp *Acetobacter* sp		*Botrytis* sp, *Fusarium* sp
16	Yellow	Rough, non-homogeneous	3.4 ± 0.2	S. *aureus* *Micrococus* sp	*Candida* sp.	*Penicillium* sp., *Rhizopus* sp., *Fusarium* sp.
17	Yellow	Rough, non-homogeneous	3.8 ± 0.1	E. coli *Bacillus* sp		*Fusarium* sp., *Rhizopus* sp., *Alternaria* sp.
18	Yellow	Rough, non-homogeneous	2.9 ± 0.1	S. *faecalis* *Bacillus* sp	*Saccharomyces* sp	*Botrytis* sp. *Penicillium* sp.
19	Yellow	Rough, non-homogeneous	3.2 ± 0.2	*Proteus* sp *Acetobacter* sp.		*Rhizopus* sp., Aspergillus sp
20	Yellow	Rough, non-homogeneous	3.9 ± 0.1	E. *coli* *Bacillus* sp		*Fusarium* sp., *Aspergillus* sp

Source: Bankole (2005)

5.2 'Pito'

'Pito' a locally produced non-alcoholic beverage was analysed for its sanitary quality for consumption (Bankole and Ogunmusere, 2006). Five markets in Abeokuta, South-Western Nigeria were sampled. The viable bacteria plate counts and the Most Probable Number (MPN) counts were high. The pH varied from slightly acidic to slightly alkaline. 'Pito' samples were examined from all the markets harboured enteric bacteria, and molds that are of food spoilage and food poisoning importance.

The mean total viable bacteria plate count, pH and MPN counts in 'Pito' samples obtained from five different markets are presented in Tables 7 and 8. The pH ranged from slightly acidic (6.6 ±0.2) to slightly alkaline (8.5 ± 0.2). This pH is conducive for the growth of microorganisms isolated especially the enteric bacteria and molds (Jay, 1992). The total viable bacteria count and the MPN counts from the various markets were quite high. 'Pito' is obtained from the leaves of Sorghum, a cereal, which is known to harbor microorganisms (Akinrele, 1970). These leaves are constantly in contact with the soil, water, other plants on the farm, all of which are habitats of microorganisms. The environmental air around the farm though not a habitat of microorganisms (Jay, 1992) contains microorganisms. Therefore, the presence of microorganisms on the sorghum leaves is not surprising. All 'Pito' sam-

ples in this study harboured bacteria of the family Enterobacteriaceae and fungi. *Proteus vulgaris*, *Klebsiella* sp and *E. coli* were present in all 'Pito' samples, *Shigella sonnei* was present in 10% of the examined 'Pito' samples and *Salmonella typhimurium* was present in 20% of the examined 'Pito' samples. *Proteus vulgaris* and *Klebsiella* sp are usually spoilage microorganisms in food while *E. coli*, *Shigella sonnei* and *Salmonella typhimurium* are food poisoning organisms and their presence indicate that the food has been faecally contaminated. The molds *Aspergillus niger* and *Rhizopus stolonifer* and *Aspergillus flavus* were present in all 'Pito' samples examined. While *A. niger* and *R. stolonifer* are well known food spoilage organisms. *A. flavus* is known as a very serious food poisoning organism which causes death (Jay, 1992). Most foods consumed harbor microorganism(s) (Jay, 1992). However the consumption of foods harbouring enteric bacteria and other food poisoning microorganisms must be avoided.

The raw material (leaves of Sorghum) of 'Pito" apart from being cleaned with water is not sterilized before being insufficiently boiled in caramelized sugar water which on cooling supplies nutrient to the surviving microorganism. The crevices of the Calabash pot (Bankole, 1991) of storage of 'Pito' for sale, the processor and the atmospheric air around 'Pito' are others ready sources of post-processing contamination.

The investigation shows that non-alcoholic 'Pito' in its present state is not sanitarily suitable for consumption. Therefore, pre-treatment of the raw material (leaves of sorghum) is suggested so as to reduce or eliminate the microorganism present in it. Thorough and prolonged boiling of the leaves in caramelized sugar solution, and the replacement of the calabash with sterile containers or packages, will also reduce or eliminate the presence of the micro-organisms.

Table 7: Mean pH and the Mean Bacterial Load of 'Pito' Samples from different markets in Abeokuta

Market	pH	Most Probable No. (MPN/ml) Coliform counts. cfu×10^5/ml	Total viable Bacterial count/ml
Lafenwa	6.6 ± 0.2	6.1 ± 0.2	2.5 ± 0.04
Iberekodo	7.6 ± 0.1	15.5 ± 0.3	0.22 ± 0.1
Kuto	7.4 ± 0.1	11 ± 0.2	20.0 ± 0
Omida	8.5 ± 0.2	0.43 ± 0.3	2.8 ± 0.1
Adatan	6.7 ± 0.1	9.3 ± 0.4	8.78 ± 0

Source: Bankole and Ogunmusere (2006)

Table 8: Enteric Bacteria, Fungi and their Percentage Frequency of Occurrence in 'Pito' Samples from five markets in Abeokuta

Market	Enteric Bacteria	Percentage Frequency of Occurrence	Fungi	Percentage Frequency of Occurrence
Lafenwa	Klebsiella sp.	100	Aspergillus flavus	100
	Escherichia coli	100	Aspergillus niger	100
	Proteus vulgaris	80	Rhizopus stolonifer	100
			Saccharomycetes cerevisiae	100
Iberekodo	Klebsiella sp.	100	Aspergillus flavus	100
	Escherichia coli	100	Aspergillus niger	100
	Proteus vulgaris	100	Rhizopus stolonifer	100
	Salmonella typhi-murium	10	S. cerevisiae	100
Kuto	Klebsiella sp.	100	Aspergillus flavus	100
	Escherichia coli	100	Aspergillus niger	100
	Proteus vulgaris	100	Rhizopus stolonifer	100
	Shigella sonnei	20	S. cerevisiae	100
Omida	Escherichia coli	100	Aspergillus flavus	100
	Proteus vulgaris	100	Aspergillus niger	100
			Rhizopus stolonifer	100
			S. cerevisiae	100
Adatan	Klebsiella sp.	100	Aspergillus flavus	100
	Escherichia coli	100	Aspergillus niger	100
	Proteus vulgaris	100	Rhizopus stolonifer	100
			S. cerevisiae	100

Source: Bankole and Ogunmusere (2006)

5.3 Bread Hygiene

The technological status and product quality of some bread making industries in Abeokuta were assessed. Microorganisms isolated from such bread included *E. coli, Staphylococci sp, Bacillus* sp, *Aspergillus niger, Penicillium citrinum* which are highly undesirable mainly because of their spoilage activities (Idowu, Atanda, **Bankole**, Uzochukwu and Olaewe, 2002). Most baked bread hardly lasted three days before growing mold, most of the bakeries were unregistered and of small scale, characterized by low capital investments, poor hygiene, the use of old bread process involving long fermentation time ranging from 2 to 10 hrs and the use of mud ovens, coupled with poor post processing handling and no packaging until it gets to the retailer. The retailer then cleans the bread with an unsterile foam thus spreading microorganism from one bread to another.

Some of the bread samples were found to harbor some pathogenic microorganisms which included the following bacterial *Escherichia coli*, *Staphylococcus aureus*, *Stahylococcus epidermidis*, *Streptococcus pyogenes*, *Bacillus subtilis*, *Lactobacillus acidophilus* and *Klebsiella pneumonia*, while the fungi included *Aspergillus niger*, *Rhizopus arrhizus*, *Penicillium citrinum* and *Saccharomyces* sp. Most of these microbes were contaminants from handling practices. Their presence is highly undesirable as they do have spoilage and food poisoning implication (Jay, 1978). Thus the microbi-

ological quality of the only bread sample which had the longest shell life of 7days had very clean factory environment and good hygiene record.

Handling practices, free access of customers to the production floor without masks and special wear and the exposure of bakeries to flies and insects all have implication on the microbiology quality of the bread produced. Shelf life of bread samples from bakeries examined in Abeokuta ranged between 3-7 days after baking. Most of the bread sample except two samples did not grow mould until 4 days after baking, probably due to the addition of antistaling agents, a common practice.

All the bakeries examined except one, made used of mud ovens. Fifty percent of the bakeries discharge their baked bread on the floor of the bakeries while 50 % of them make use of specially prepared surfaces for discharging bread. Most of the bakeries examined allowed free access of customers to every part of the production floor without special in-door wears. However, factory workers wear indoor coats to avoid contamination. Although, most of the bakeries clean their equipment and machineries regularly at the end of every shift, quite a good number of them do not screen their bakeries from flies and insects.

5.4 Ready-to-eat foods

(i) Vegetables

Ready-to-eat (R-T-E) vegetables – (Cucumber, Carrot, Lettuce, Cabbage) and prepackaged salad sold on the streets of Lagos, Nigeria were bacteriologically assessed. One hundred and sixty samples of four R-T-E vegetables and 56 samples of fresh retailed salad were examined for aerobic plate counts (APC), total coliform, faecal coliform and total staphylococcal counts. The mean aerobic plate counts (APC) for vegetables ranged from 1.36 x 10^7cfu/g of cucumber to 4.20 x 10^9cfu/g of Lettuce, coliform counts ranged from 5.20 x 10^3cfu/g to 6.32 x 10^5cfu/g while staphylococcal counts ranged from 2.01 x 10^6cfu/g to 6.47 x 10^6cfu/g. The APC, total coliform and staphylococcal counts of the salad samples were 6.10 x 10^7cfu/g, 1.86 x 10^5cfu/g and 7.82 x 10^6cfu/g respectively. *Staphylococcus* sp and *Enterobacter* sp were the most predominant bacteria while *Bacillus cereus* was also detected in the vegetables and salad. *Listeria* sp was detected in 15% of Lettuce leaves and 10% carrot samples. All these bacteria isolates are of food poisoning importance. While these street foods provide a source of readily available inexpensive nutritional meals to populations and a source of income to the vendors, it can also pose risks to health (Omemu, Edema and **Bankole,** 2005).

(ii) Smoked fish

Cold smoked fish examined showed the presence of *Bacillus*

sp, *Micrococcus* sp, *Staphylococcus aureus, Staphylococcus epidermidis, Escherichia coli, Klebsiella* sp, *Proteus morgani and Pseudomonas* sp which are of bacteria origin; moulds isolated included *Aspergillus* sp, *Penicillium* sp and two yeast strains, *Candida* sp, and *Rhodotorula sp*. Total viable bacterial count revealed 2.2 x 10^4/g – 9.3 x 10^5/g from the intestines, 3.4 x 10^4/g – 9.1 x 10^5/g from the skin and 1.9 x 10^4/g – 6.5 x 10^4/g from the gills. The microbial isolates and bacterial counts are of food poisoning and food spoilage significance. (Ezeri, **Bankole** and Akinyemi, 2001). Some of these bacterial floral are from the broodstock of intensive fish farming systems. (Akinyemi, Ezeri, Obasa, and **Bankole,** 2009).

(iii) Pounded yam and 'Amala-isu'

Pounded yam, a cherished traditional food produced by physically pounding hot cooked peeled yam with mortar and pestle, has a very short shelf-life. It was observed to harbour bacteria (*Bacillus* sp *Pseudomonas* sp, *Streptococcus* sp, *Erwinia* sp, *Serratia* sp, *Escherichia coli, Staphylococcus aureus, Staphylococcus epidemidis, Clostridium* sp, *and Micrococcus* sp, yeast (*Saccharomyces* sp, and mold (*Aspergillus niger, Aspergillus flavus, Penicillium* sp, *Rhizopus* sp, *and Geotrichum* sp). While some of these isolates are of soil origin and contaminated the pounded yam through the yam tuber, some isolates are of human origin. The viable bacterial counts were high (4.0 x 10^5 – 5.1 x 10^7cfu/gm) while the almost neutral pH (6.5 – 7.1) and the room temperature

of processing and storage of pounded yam favoured the growth of these microorganisms, hence, their spoilage of the food. Improved food and personal hygiene may help in lengthening the shelf-life (Bankole, 2006).

"Amala –isu" a cherished delicacy in some parts of West Africa especially in Nigeria and neighbouring Benin Republic is a highly perishable food having a short shelf life usually between six to twelve hour after preparation. Two varieties of dry yam chips; white yam and water yam were used as raw materials in the preparation of yam flours for "Amala-isu". All the flours examined harboured microorganisms with white yam flour harbouring more types of microorganisms (Table 9). While some of the chips were milled with laboratory milling machine, some were milled with commercially used milling machine. The Laboratory machine milled flour had the lowest viable bacterial count (Somorin, **Bankole,** Omemu and Atanda, 2011).

Table 9: Total viable bacterial count and types of bacteria isolated from laboratory and commercially milled dry yam chips from different locations in the South-West of Nigeria

	Laboratory-Milled		Commercially-milled	
Sample location	Total viable Bacterial count (cfu/g)	Bacteria Isolated	Total viable Bacterial count (cfu/g)	Bacteria Isolated
Abeokuta	1.88×10^{4a}	Bacillus megaterium, Klebsiella oxytoca, Staphylococcus aureus, Proteus vulgaris, Enterobacter cloacae, Corynebacterium sp, Pseudomonas aeruginosa	4.33×10^{5a}	B. megaterium, K. oxytoca, S. saprophyticus, S. epidemidis, Corynebacterium sp, Edwardsiella tarda, B. badius
Ibadan	3.85×10^{3b}	B. megaterium, K. oxytoca, S. aureus Ps. Aeruginosa	4.32×10^{5a}	B. badius, B. magaterium, S. saprophyticus
Mushin	1.81×10^{4a}	S. aureus, P. mirabilis, P. vulgaris, B. megaterium, E. cloacae	2.5×10^{5a}	Escherichia coli, B. megaterium, Enterobacter aerogenes, S. saprophyticus, K. pneumoniae, S. aureus, S. epidemidis

Mean values within a column with the same letter are not significantly different ($p>0.05$)
Source: Somorin, Bankole, Omemu and Atanda (2011)

5.5 Microorganisms in the local processing of foods and drinks

Microbiological and related investigations have been carried out on "nono," a Nigerian fermented milk product, with the primary purpose of determining the microbial and physico-chemical changes which occur in the fermentation, the micro-organisms involved, suitable starter cultures and other conditions for optimizing the fermentation and for preserving the product. (Bankole, 1991; Okagbue and Bankole, 1992; Bankole and Okagbue, 1996).These studies showed that pH dropped from 6.8 ± 0.1 to 4.3 ± 0.1 during the traditional production of "nono." There is a corresponding increase in the titratable acidity. "Nono" is therefore an acid food (Bankole and Okagbue, 1996).

Analyses of fully prepared "nono" showed that there were slight increases in the content of minerals which occur in milk. The following proportions of minerals were found in "nono":-

K (24.0 – 59.0 mg/100ml),
Ca (13.5 – 28.9 mg/100ml), Mg (2.4 – 6.4 mg/100ml),
Zn (0.3 – 0.7 mg/100ml), Fe (0.0 – 0.9 mg/100ml),
Na (8.0 - 24.0 mg/100ml), P (15.8 – 44.6 mg/100ml).

Copper was not detected in "nono" samples examined (Okagbue and Bankole, 1992).

Crude protein was relatively high (1.2 – 5.7%) in "nono." This indicates that the product is suitable as a dietary source of protein. An increase in fat was also observed. Many microorganisms were isolated from "nono" but only *Streptococcus cremosis*, *Streptococcus lactis, Streptococcus diacetilactis, Lactobacillus cellobiosus, Lactobacillus brevis,* and *Saccharomyces cerevisiae* were incriminated in its fermentation. Raw milk could not be fermented into "nono" with pure cultures of single strains of the above microorganisms but a combination of a *Streptococcus diacetilactis, Lactobacillus brevis* and *Saccharomyces cerevisiae* (Okagbue and Bankole, 1992).

Out of four temperatures tested, 25^{o}C and 30^{o} C were suitable for production of acceptable "nono"; 15^{o}C and 37^{o}C were unsuitable (Bankole and Okagbue, 1996). Although stationary and agitated fermentations yielded acceptable products, the stationary method should be preferred because agitation is mechanical process and would increase costs in a commercial operation. The open system of fermentation would also be preferable to the closed system of "nono" fermentation. "Nono" could be stored at 4^{o}C with retention of its microbiological, biochemical and aesthetic values, although its texture and its viscosity would slightly change.

Some lactic acid bacteria isolated from "nono" were inhibitory to the growth of *Staphylococcus aureus* and *Escherichia coli*. If the

lactics produce antimicrobial agents during their activity in "nono" production, the agents would be useful for safeguarding the product from growth of the two organisms which could constitute health hazards.

No bacteriophage was detected in the "nono" samples examined in this study. Thus the potentially useful starters isolated from these studies are relatively free from lytic bacteriophages and can be propagated and used for large scale production of "nono."

The shelf-life of "nono" which could be maintained at 4^{o}C for up to 12 days can be extended or improved by packaging the product inside sterile material. The packaging would facilitate distribution, sale and possible introduction of "nono" to other parts of the world.

Overall, the work provided considerable information on the microbiological and physico-chemical aspects of "nono" fermentation and on the nutritional value of the fermented product. It established some possible methods for optimizing and enhancing its acceptability and for prolonging its shelf-life. Briefly, they are: use of suitable starter cultures consisting of *Streptococcus sp.* and *Lactobacillus sp*., use of a suitable range of temperatures (25^{o}C – 30^{o}C), an open or closed fermentation system without agitation and preservation at 4^{o}C for at least

12 days (Bankole, 1991).

5.6 Foods and food materials as Microbiological growth media

Waste maize cobs were processed into microbiological growth medium for fungi (Bankole *et al.,* 2006). Cob from maize (*Zea mays*) is available in abundance during the raining season as a waste material and constitutes nuisance. These cobs were variously processed (roasted, fresh, premature, cooked salted, uncooked salted) into powder as raw materials to prepare growth medium (Cob Agar) for moulds (*Rhizopus nigricans, Aspergillus niger, Trichoderma viride, Alternaria tenuis, Fusarium* sp *and Penicillium* sp*).*

The mold growth on Cob Agar media was compared to mold growth on Potato Dextrose Agar (PDA) and Sabouraud Dextrose Agar (SDA) – which are the recognized microbiological medium for growth of mold. Cob Agar media had growth similar to PDA but supported mold growth better than SDA. Cost of PDA per litre was found to be approximately N1000 PDA/litre while cost of Cob Agar per litre was found to be approximately N400.

Two species each of yam (*Dioscorea rotundata and Dioscorea alata*), Cocoyam (*Xanthosoma* sp and *Colocasia esculenta*) and Sweet Potato (*Ipomea batata*- Red and White) which are local

common plant tubers in Nigeria were evaluated as raw materials for the growth of fungi (*Aspergillus flavus, Rhizopus nigricans, Saccharomyces cerevisae*). These raw materials were used in the cooked and the uncooked forms. The pH of the raw materials were similar with a reading of around 5.6 while their proximate analysis varied with the following recording highest: uncooked water yam with moisture content of 22.95%, cooked water yam, with 90.69% dry matter, uncooked white potato with fat content of 2.03%; uncooked cocoa yam (*Xanthosoma sp*) with crude protein of 4.67%; uncooked red potato with crude fibre and ash content of 2.27% and 3.31% respectively and uncooked white potato with carbohydrate content of 80.75%. Inoculating under the same condition of air and mesophilic temperature and using commercially prepared Potato Dextrose Agar as control; all media supported the growth of inoculated fungi with cooked yam and cooked cocoyam raw materials giving the highest growth support. The incorporations of Dextrose gave faster initial growth though growth with or without Dextrose were similar by the 3rd day of incubation. Cocoyam (*Xanthosoma* sp, and *Colocasia esculenta*) and water yam (*Dioscorea alata*) are cheaper materials than Irish potato (*Ipomea batata*) and are readily available in Nigeria. They can comfortably replace Irish potato in the preparation of common laboratory growth medium for fungi to reduce foreign spending. These plant tubers though known as intermediate foods can be destroyed by fungi (Bankole *et al.*,

2006a).

5.7 Spices as food preservatives

Nigerians love spices. Table 10, shows the pH and the bacterial load of local spices examined (Makinde, 1979). The pH ranged in the slightly acidic region while they all harbor high total viable bacteria count per gram. Apart from ginger and Negro-pepper, the others did not harbour *Staphylococcus aureus*. The spices could decrease or increase the bacterial load of food (Makinde, 1979) while some such as Tamarind completely eliminated coliforms and *Bacillus cereus* in kunutsamiya (Bankole *et. al*., 1999) hence, acting as antimicrobial agent.

Kunutsamiya is a traditional non-fermented non-alcoholic beverage consumed in Northern Nigeria. It is produced mainly from millet but sometimes sorghum and maize are used. It is normally flavoured with black pepper, ginger and tamarind to enhance the taste and aroma and also to serve as purgative and cure for flatulent conditions. The popularity of kunutsamiya is due to its characteristics sweet sour taste and the general belief that it enhances lactation in nursing mothers (Bankole *et al.,* 1999).

Table 10: The pH, and bacterial load of local spices

Name of spice	pH	Most Probable Number MPN/gram	Bacteria counts/gram of sample Total Viable bacteria	Coliform Staph .sp.	
Ginger	5.7	1.7×10^5	2.59×10^9	9.0×10^5	1.16×10^6
Clover	4.3	0	4.3×10^6	0	0
Grains of Paradise	5.8	2.30×10^5	4.8×10^8	5.0×10^4	0
Negro-pepper	4.6	2.2×10^6	7.9×10^6	1.50×10^5	2.0×10^5
Red-pepper	4.7	2.30×10^5	9.4×10^7	1.0×10^5	0

Source: Makinde (1979)

Plate 6: Clover
Source: Makinde (1979)

Plate7: Red-pepper

Source: Makinde (1979)

The preservative activities of 'kuka', the cream of tartar of Baobab fruit, a local spice was studied, with respect to its effects on the total viable bacterial count especially the coliforms and staphylococcal organisms in 'nono', a product of fermented milk (Bankole, 2005b). Increasing the concentration of 'kuka' from 1% to 50% resulted in an inhibition of the bacteria present in 'nono' with attendant decrease in pH. Thus, 'kuka' has some preservative effect on 'nono'. 'Kuka' is often used to thicken 'nono'; being a white powder that can be made into a liquid, resembling 'nono'. Okoh (1973), found that 'kuka' has a high Calcium level (2.7% dry weight) while Carr (1955) and Nicol (1957), recorded a good ascorbic level of 317 mg percent and 373 mg percent (wet weight) respectively for it. Thus 'kuka', apart from being effective in reducing bacterial population in 'nono', may also enhance the nutritive value. Although 'kuka' is used to adulterate and increase the volume of 'nono' for sale, it is actually useful in improving the bacteriological quality of 'nono'. However, the fact that it has been suggested that its tannin content could complex proteins of bacteria gives cause for concern since it may also complex the protein of milk and render it unavailable for absorption. More data are required to enable a scientific recommendation to be made about its usefulness.

The cold water extracts of the leaves of some Asteraceae (*Vernonia amygdalina, Crassocephalum biafrae*) commonly eaten as

vegetables in southwest were examined for their antimicrobial effect on some enteric pathogens- *Staphylococcus aureus, Escherichia coli* and *Salmonella typhi*. The enterics were inhibited by *V. amygdalina* and *C. biafrae* and can therefore be used as antimicrobial agents (Bankole *et al*, 2003).

Nigeria loses 30-50% of its fish harvest to microbial spoilage (Oladosu-Ajayi, R.N., George, F.O.A., Obasa, S.O., Ajayi, A.A. and **Bankole, M.O**., 2011).

Some natural plants were examined for their antimicrobial properties. On fish spoilage microorganisms, ethanolic, cold and hot water extracts of grape fruit (*Citrus paradisa*), peel, pawpaw (*Carica papaya*) seed, and black pepper (*Piper guineese*) seed at five different concentrations were tested for their antimicrobial properties on fish spoilage microorganism associated with catfish (*Clarias gariepinus*).All these natural plants have antimicrobial effects on the eleven microorganisms tested with the grape peel (3.70 $\pm$ 0.40mm) having the highest antimicrobial activity, followed by black pepper (2.68 $\pm$ 0.42mm) and then pawpaw seed (2.19 $\pm$ 0.32mm) inhibition zones (George, Ephraim, Obasa and **Bankole,** 2009).

5.8 Sources of Food Contamination

Some well water, (Makinde, 1975) and sachet water (Edema, Omemu, Atayese and **Bankole**, 2011) were examined for their potability. These waters were loaded with microorganisms. Man had long been conscious of the importance of the type of water used for domestic purposes.

Locally, *Moringa oleifera* Lam. is used for water purification. Investigation (Oluwalana, **Bankole,** Bolaji, Martins and Alegbeleye, 1999) of this plant as a water purifier showed that it clarified the water, reduced the microbial load drastically but did not sterilized the water.

Lack of a drier for grains, fermented powdered foods etc. for drying to preserve has led to food contamination. Many such foods are spread on tarred roads or cemented floors and at best on mats. Investigations of these mats were shown to have high microbial load which could be passed to the food being dried (Bankole *et al.,* 2000).

Locally produced toilet tissue papers from 10 different manufacturers were severally examined for the presence of microorganisms. All the samples examined harboured microorganisms, an indication of a probably inadequate microbiological processing. They all had similar total viable microbial count ranging from 0.74×10^4 to 4.2×10^4 for bacteria and $3.2 \times$

10^3 to 7.0 × 10^5 for molds. The bacteria isolated include *Staphylococcus aureus*, *Salmonella typhimurium*, *Proteus intermedium*, *Proteus vulgaris*, *Escherichia coli*, *Enterobacter aerogenes*, *Pseudomonas* sp, and spore formers such as *Bacillus megaterium*, *Bacillus subtilis* and *Bacillus mesentericus*. The fungi include *Aspergillus niger*, *Aspergillus oryzae*, *Penicillium nigricans*, *Torulopsis* sp, *Candida utilis*, *Candida tropicalis*, and *Saccharomyces* sp. These microorganisms are of pathogenic, food poisoning, food spoilage, and epidemic importance. Tissue toilet papers locally produced are microbiologically unfit for toilet use and unsafe for wrapping food for direct consumption (Bankole and Omemu, 2006b).

The palms of 87 food vendors in Abeokuta metropolis were sampled for the presence and types of microorganisms. The food handlers were grouped into six categories based on the type of vending sites: hawkers (15), roadside (13), open air (15), closed /roofed (21), restaurants (12) and hotels vendors (11). Only 43.7% of the 87 vendors sampled had undergone the annual medical checkup while 56.3% had never done the checkup. None of the hawkers sampled had ever done the medical checkup while all the hotel food handlers had the health certificate indicating that they have done the routine medical checkup. Bacteria isolated from the hands of the food handlers included *Staphylococcus aureus, S. epidermidis, Alcaligenes* sp. *Bacillus subtilis, Listeria* sp. *Enterobacter* sp, *Escherichia coli, Klebsiella aerogenes, Proteus vulgaris and Vibrio cholerae*. The

fungi were *Rhizopus* sp. *Aspergillus niger* and *Sachharomyces cerevisiae*. This suggests that food handlers were possible sources of microorganisms implicated in food poisoning and food spoilage. Proper policing of vendors to ensure that they undergo the annual physical and medical examinations and proper education of food handlers on personal hygiene is recommended (Bankole *et al.,*2009).

Nigeria produces a variety of raw foods which should give more than enough food on the table, however, this foods are poorly handed microbiology during and after harvest. A lot of these foods are exposed to the air, soil and water which pollute and destroy them. The right storage facilities are either not available or inadequate. A visit to the market observed some sources of such microbial contamination, as shown below:

Plate 8: Some yam tubers laid on bare soil for sale. Some of which are infected with fungi.

Plate 9: Sweet oranges poorly stored for sale. Some of these oranges already have microbial attack that could contaminate healthy ones

Plate 10: Rottened and healthy Pineapple fruits stacked together

Plate 11: Tomatoes fruits laid on raffia mat for sale

Plate 12: Variety of pepper laid on cellophane nylon on the floor for sale

Plate 13: Dried yam chips used to make yam flour undergoing mould spoilage

Plate 14: Different food products: gari, elubo-isu, rice beans, wheat grains, maize grains exposed for sale

Plate 15: Cow meat fresh from abattoir laid for sale in the market

Plate 16: Smoked fish displayed for sale in the market

Local commercial foods for consumptions are often processed in the open air, with contaminated utensils, water and hands. Food vendors, especially hawkers do not package or protect their ready-to-eat food product and leftovers are never refrigerated or reheated before use. Hence, the microbial destruction of food that should be on the table. In the manufacture of food for consumption initial raw materials are never picked or cleaned or standardized before use, methodology of production varies depending on the producer while the end products vary widely from batch to batch even from the same producer.

6.0 WAY FORWARD

Africa, especially Nigeria, has a lot of raw and processed foods which are off-table through improper processing and microbial spoilage. In order to harness and put these foods on the table, the following steps should be taken into consideration:

A. Optimization of shelf-life of raw materials

Encouragement of environmental and personal hygiene, good storage facility, knowledge of the presence and role of microorganism in food will aid longer shelf-life of raw food materials.

B. **Compilation of Indigenous Knowledge in Fermentation**

In Africa, food preparation is an ART and not a SCIENCE hence there is no uniformity in the products. The knowledge of how to make these products has often been passed down from parent to child (usually mother to daughter) and belongs to that undervalued body of "indigenous knowledge" which is often lost as technologies evolve and families move away from traditional food preservation practices. Therefore, food preparation procedure should be scientific and written.

C. **Understanding and Optimization of Traditional Processing**

Most traditional food preparations products are made by natural fermentations carried out in a non-sterile environment. The specific environmental conditions cause a gradual selection of micro-organisms responsible for the desired final product. This is appropriate for small-scale production for home consumption. However the method is difficult to control and there are risks of accompanying micro-flora causing spoilage and unsafe products. If the processes are to be refined, with a view to production on a larger scale, it is essential to have a scientific understanding of the food processes. This can be developed by:

i. The isolation and characterisation of the essential micro-organisms involved;
ii. The determination of the role of external factors in food preparation and the effects of these on the metabolism of micro-organisms
iii. The investigation of the effects of pre-treatments of raw materials on the food process
iv. The identification of the options for further processing and how these affect the taste and texture of the product.

Research in this area is capital intensive and may require funding. It requires the use of sophisticated equipment and reagents backed with a consistent energy and water supply which are not always available in developing countries. To meet the current and future challenges in developing countries, it is important that these countries develop the capabilities to benefit from improvements in food methodologies, particularly those involving microorganisms.

D. Starter Culture Development

Starter cultures are those microorganisms that are used in the production of fermented food products such as yogurt and cheese. A starter culture can provide particular characteristics in a more controlled and predictable food fermentation. The primary function of lactic starters is the production of lactic acid from lactose. Other functions of

starter cultures may include the following:

- flavour, aroma, and alcohol production
- proteolytic and lipolytic activities
- inhibition of undesirable organisms

Developing pure starter cultures for traditional food products are important for the provision of quality and safe food. Developing these by laboratory selection or genetic engineering is not viable. A more feasible approach would be to exploit the ecological principle of inoculum enrichment by natural selection.

E. Quality Control

From harvest of the raw materials to storage of processed food products in the home, a key concern is suppressing the growth of unwanted organisms that may spoil food. Meeting safety standards while maintaining organoleptic quality is a challenge that can be met only with sophisticated technological efforts.

Inadequate quality control can have an adverse effect on local demand for the product. This is particularly a problem for small-scale traditional production. In modern industrial applications, equipment and processes are controlled using expensive technology, resulting in a consistent product of a known quality. Traditional practises take place in a less predictable en-

vironment. This can result in mistakes.

Based on this, strategies such as the Hazard Analysis and Critical Control Points (HACCP) tool (Table 11), that would guarantee the microbiological safety of food products should be employed.

Table 11: The seven principles of the HACCP system,

	Principle	Activity
1	Conduct a hazard analysis	List all potential hazards associated with each step, conduct a hazard analysis, and consider any measures to control identified hazards
2	Determine the Critical Control Points (CCPs)	Determine Critical Control Points (CCPs)
3	Establish critical limit(s)	Establish critical limits for each CCP
4	Establish a system to monitor control of the CCP	Establish a system of monitoring for each CCP
5	Establish corrective actions	Establish the corrective action to be taken when monitoring indicates that a particular CCP is not under control
6	Establish verification procedures	Establish procedures for verification to confirm that the HACCP system is working effectively
7	Establish documentation and record keeping	Establish documentation concerning all procedures and records appropriate to these principles and their application

Source: (CAC, Committee on Food Hygiene, 1997)

Areas that require improvement:

- Selection of good quality raw materials
- Processing under correct conditions
- Ensuring high standards of personal hygiene by the food processors
- Ensuring the processing area is sufficiently clean
- Using correct packaging

F. Knowledge Sharing and Capacity Building

Local foods often have a stigma attached to them – they are considered as poor man's food. As soon as a family can afford to buy processed foods, they move away from consuming local foods especially fermented foods. This is a pity, because local food products have many nutritional advantages which surpass western-style fast foods and processed foods.

It is not difficult to gain access to village people, both to collect the traditional information and to disseminate improved practices. Numerous organisations are involved in field projects. They can be used to organise training sessions and group meetings for the dissemination of new methods, for example, for the use of pure starter cultures.

One of the problems likely to be encountered is gaining access to starter cultures and other improved methods. Microbi-

ologist should work on the production of starter cultures while agricultural extension services should take responsibility for the promotion and the supply of starter cultures at a price which is affordable.

G. Legislation and Enforcement

Agencies of government charged with ensuring food safety (NAFDAC, Standard Organization of Nigeria (SON), Environmental Health Officers etc) should be alive to their responsibility. Food handling practices among small scale processors should be regularly monitored and sanctioned for unhygienic practices and where necessary training should be given to small-scale processors on best practices in food processing and handling. This will avert the intermittent situation of food poisoning attributed to consumption of contaminated foods.

7.0 CONCLUSION

Microorganisms in foods are only perpetuating their lives though in the process they may be detrimental (taking food off the table) or beneficial (bringing food to the table).

In Africa especially in Nigeria, indigenous food preparation is an art. A processor does not produce the same food to give same physical and nutritional constituent and even aesthetic characteristics; each production varies. A change of food

preparation from Art to Science will control the role of microorganisms in food preparation and aid same end product. This will increase food material on the table form farm.

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