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MICROORGANISMS IN FOOD: PROBLEMS AND PROSPECTS

BY

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OLABISI ONABANJO UNIVERSITY
AGO-IWOYE.

TUESDAY, 30TH OCTOBER, 2012.

Dedication

Dedication to my late patents Pa Julius Babafemi Adebajo and Mrs Felicia Adebajo

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The Vice, Chancellor,
Deputy Vice Chancellor,
The Registrar,
Other Principal Officers of the University,
Provosts of Colleges and Postgraduate School,
Deans of Faculties,
Colleagues and Friends form Sister Universities and Research Institutes,
Your Royal Highnesses, Chiefs, Lords Spiritual and Temporal,
Gentlemen and Ladies of the Press here present,
Distinguished Ladies and Gentlemen,
Greatest OOUITES

PREAMBLE

I am delighted to welcome you all to this Inaugural Lecture, and I feel highly honoured by your presence. It is the 58th Inaugural Lecture of this great University, the tenth from the Faculty of Science and the first from our young Department of Microbiology.

My academic career in this great University commenced in December 1985 as an Assistant Lecturer in the defunct Biological Sciences Department. To the glory of God, the University of Ibadan awarded me a Ph.D. degree in 1988. I rose through the ranks to becomes a Reader in July 2003 and was eventually promoted to the position of a Professor on 1st October, 2003 under the able leadership of Professor Afolabi Soyode. I am forever grateful for that elevation and recognition and I remain cognizant of the enormous responsibilities that honour simultaneously confers. May the Lord's name be praised Amen.

In this Inaugural Lecture titled "Microorganisms in Food: Problems and rospects", I intend to give simple and brief insight to the problems food associated nicroorganisms cause humans most especially those problems due to consumption f microfungi in food. The ultimate aim is to provide effective control measures rough appropriate education of consumers and producers of such food products. he beneficial aspects of some microorganisms in food shall also be highlighted.

1. INTRODUCTION

The control of food safety and quality is of utmost importance to a nation because of the implications for development. The increasingly concern of the government and the general public in ensuring that the food available to the people will be free from both chemical and biological contaminants has necessitated that some control measures are put in place.

The promulgation of food laws and regulations is one of the methods by which a government can effectively control the food safety and quality in a nation. The law may involve the pre-determination of permissible levels of specified objectionable components in the food. This in turn will, require that standard, tested and trusted laboratory analyses will from time to time be carried out on food samples available to the people. In this lecture, the findings of some of the research studies conducted on some indigenous food snacks are highlighted with particular attention to the tiger nuts which has been described as highly beneficial under utilized crop waiting to be promoted for increased consumption.

2. MICROORGANISMS IN FOOD

Microorganisms are microscopic plants and animals, many of which are single called. Microbiology is the study of such organisms.

Microorganisms are ubiquitous meaning that they are found in virtually all habitats and materials both organic and inorganic. They are constantly associated in a variety of ways with all types of food we eat (Dave and Ghaly, 2011). By convention and for convenience of study, microorganisms in food are usually categorized as follows: bacteria, yeasts, moulds and viruses. There are other distinct types of microorganisms: algae, lichens and protozoans; they are considered to be of less importance in food microbiology.

Bacteria

Bacteria are prokaryotic microscopic organisms lacking chlorophyll though a few may have bacteriochlorophyll. They basically have four major shapes: (i) spherical (coccus) with an average diameter of 1um or less (1m = 10^{-3}mm or 10^{-}

^{6}m), (ii) rod-shaped (bacillus) which are 2 – 5 Nm long, (iii) spiral (spirillum) which have similar size to bacilli, (iv) curved (vibrio). Occasionally bacteria may be filamentous and forming a mycelium. They are non-motile or motile by one or more flagella. Multiplication is mostly by simple fission. They occur in very large numbers in favourable habitats. Because they are achlorophyllous, bacteria are mostly saprophytes or parasites although a few are autotrophic, either obtaining energy by oxidation processes or from light with the aid of bacteriochlorophyll.

Yeasts

These are widely distributed unicellular (5-10μ across) fungi occurring in all possible shapes – circular, oval, globose, ellipsoidal, rectangular, elongated, dumb-bell-shaped and even triangular. All yeasts can reproduce asexually mostly by budding or fission or in some few species by an intermediate system called bud fission. Sexual reproduction is mostly by a process called conjugation has only been observed in the yeasts grouped under Sub-Division Ascornyeotina. These are the true or perfect yeasts. The other category comprises yeasts that have not been observed to reproduce sexually. These are the false or imperfect yeasts.

Moulds

These are multicellular, filamentous fungi whose growths on suitable substrates like foods are characterized by the cottony or fuzzy appearance. The main body of mould consists of several intertwined filaments called hyphae. A network of hyphae is termed mycelium. Moulds generally reproduce mainly by production of very enormous and easily dispersed asexual spores. Some moulds (termed perfect moulds) also produce sexual spores equally in large quantities.

Viruses

Viruses are non-typical or unusual "microorganisms" that may also be present in food. They are very small acellular microorganisms with diameters of 15-400nm (1nm = 10^{-3}um or 10^{-6}mm or 10^{-9}m) unlike the bacteria, yeasts and moulds, viruses are sub-microscopic (i.e. cannot be seen under light microscope) agents described as obligate intracellular parasites with cellular specificity. The

virion (technical term for virus) consists of nucleic acid surrounded by a protein coat. The nucleic acid is called nucleoid (which may be DNA or RNA, never both). Viruses multiply by independent synthesis of their constituents, nucleic acid and proteins, and their assembly rather than by growth and division.

Microbial Contamination of Food

The Vice Chancellor, Sir, the food microbiologist is concerned with sources and process of food contamination mainly for control purposes and to keep microbial population on or in the food as low as possible. This will ensure a longer shelf life for the food and reduce the incidence of outbreak of microbial foodborne diseases after ingestion. Besides, when contamination is reduced, it is easier to control or destroy the microorganisms with food preservation techniques.

Due to their very small sizes, it is very difficult to know at least at the initial stages when microorganisms get in contact with food. However, when conditions of storage are favourable the contaminating microorganisms multiply rapidly and eventually their numbers in food become very high. At this point the physical appearance of the microorganisms becomes obvious. Also changes in the favour and odour of the food may be noted. On the other hand, when the storage conditions are not so conducive for microbial growth, the physical appearance, flavour and odour of the food may remain unchanged, thus it is easy to consume contaminated food without realizing it (Adebajo, 1993a). The hazards associated with the consumption of such contaminated food are well documented (Smith and Hacking 1983; Adebajo and Idowu, 1994) and have necessitated the study of sources of microorganisms found in food. Such sources include: soil, water, sewage, plants, animals, intestinal tract of humans and animals, animal feeds, animal hides, food utensils, processing equipment, ingredients, food handlers, product to product, packaging materials, air, etc. Indeed the sources are almost inexhaustible. However, a brief consideration of the most important sources is pertinent here.

Soil

Soil is the natural habitat of many types of microorganisms and it is the chief source of contamination. Fertile soils have very high microbial spectrum and

total counts which usually vary with the types of soil as well as the environmental conditions. The total microbial counts can vary from a few organisms in sandy soil to as many as 10^{10}/g in fertile soil (Banwart, 1980).

Research findings (Ogundero and Adebajo, 1992; Willey *et al*., 2011) have shown that nearly every important microorganism can come from soil. This is particularly true for various kinds of moulds and yeasts and species of the bacterial gerrera including *Escherichia, Streptococcus, Bacillus, Pseudomonas, Clostridium, Alcaligenes, Proteus, Enterobacter, Acetobacter, Micrococcus, Flavobacterium,* etc.

Microorganisms in soil contaminate tubers or root crops by direct contact. Soil particles blown by wind or splashed by rain may be deposited on fruits or vegetables of crops such as cabbage, water melon, strawberries, peas or beans that grow on or near the ground level. The microbial numbers and types on crops are influenced by the degree of contamination of the soil in which they are grown.

The harvesting practices also influence the level of soil contamination. Mechanical harvesting for example has increased the amount of soil contamination as well as breakage of fruits and vegetables. Cereals crops in particular are contaminated during harvesting.

Water

Natural waters, in addition to their natural or normal flora also contain microorganisms from soil, air, animals including sewage. Consequently, various species of bacteria, moulds yeasts and including protozoans which are microscopic animals, could be found in water. Viruses are also found in water. They attach to suspended particles and remain infective (Vasickova *et al.,* 2005). Indeed water is still the main carrier of organisms that cause gastroenteritis in man.

Water contacts food during production, harvesting and processing. If the water used for irrigation of various crops is contaminated, the fruits and vegetables in particular can be potential health hazards (Banwart, 1980). This is so because many fruits and vegetables are eaten raw or processed under low to moderately high temperature before consumption. It has therefore became necessary to always

wash fruits and vegetables in several changes of treated or safe water before they are served for consumption.

Seafoods and other foods from fresh water environment are harvested from water. They are therefore usually contaminated by microorganisms from the water medium. Several workers (Hobbs and Roberts, 1987; Vasickova *et al.,* 2005) have reported that microorganisms in the water contaminate the surface, gills and intestinal tract of fish and shell fish. The occurrence of faecal coliforms in fish is a reflection of the pollution level of their water environment. *Escherichia coli* is used as an indicator of faecal pollution of water. The usual test for possible sewage or faecal contamination is the presumptive test for coliform bacteria. When dilutions of the water are cultured in fermentation tubes of lactose broth at 35 to 37^0C, the production of acid and gas is a positive presumptive test indicating the probable presence of coliform bacteria. The test can be confirmed and completed by standard methods (Varnam and Evans, 1996).

Sewage

The use of untreated sewage to fertilize plant crops is a major cause of contamination with human pathogens, especially those causing gastrointestinal diseases. In addition to the pathogens, coliform bacteria, anaerobes, enterococci and other intestinal bacteria can contaminate the foods from this source. As highlighted above, natural waters contaminated with sewage contribute their microorganisms to fish and other food plants and animals from aquatic environments. It is important to note that even the treated sewage contributes microorganisms to food though at much lower numbers and fewer pathogens. In the United Kingdom, Hobbs and Roberts (1987) documented that raw domestic sewage contained 10^9 coliforms/g and effluent from a treatment facility had 10^6 coliforms/g. The faecal streptococci were at levels of 10^6/g and 10^4/g, respectively. James (1992) recorded salmonellae in 94% of the effluents from sewage treatment plants. The survival of enteric viruses through treatment plants had also been reported by several investigators (Vasickova *el al.,* 2005).

When added to soil, for example, when used as fertilizer or as a result of leakage from the treatment plant, sewage contributes pathogens which may survive in the soil for periods long enough to contaminate the harvested crop.

Plants

It is a common knowledge, and also generally assumed that many or most soil and water microorganisms contaminate plants. However, only a very small number of such organisms find the plant environment suitable for their growth and many will eventually loose their viability. Those that are able to survive do so because they are able to adhere to plant surfaces and obtain nutrients from the plant. Major examples of such microorganisms adapted to plant surfaces include the lactic acid bacteria such as *Lactobacillus brevis, L. plantarum*, and some yeasts. Others that are commonly associated with plants include plant pathogens in the genera *Pseudomonas, Xanthomonas, Corynebacterium, Micrococcus, Curtobacterium* and fungal pathogens among several genera of moulds.

Animals

The chief sources of microorganisms from animals include the surface flora, the flora of the respiratory tract, and the flora of the gastrointestinal tract. The microbial load of the gastrointestinal tract in particular is very high with total aerobic count ranging from 10^6 to 10^{11}/g and about the same number for anaerobes. Coliforms, enterococci, lactobacilli and bacteroides are the predominant organisms. The hides, hoof and hair of large animals and feathers and feet of poultry usually carry large numbers of microorganisms from soil, manure, feed and water. Wild animals contaminate crops and stored products. Insects, birds, rodents and several other vermin destroy the protective covering on foods thus resulting in contamination. Many of these animals may transmit potential human pathogens and spoilage microbes to the food they contaminate.

Animal Feeds

The microbial content of feed will eventually be transferred to poultry and other farm animals. For example, feed is an important source of salmonellae to

poultry and other farm animals. In the case of some silage, it is a known source of *Listeria monocytogenes* to diary and meat animals.

Food Utensils

Some of the microorganisms present on vegetables, grains and meat for example, will eventually be transferred to the surfaces of utensils used for their preparation. Similarly, the cutting board, knives, turning stick, beaters and grinders are contaminated right from the first time they are used and this will lead to a build-up of organisms on the surfaces of most food utensils thereby resulting in constant contamination of food prepared in them. The food utensils particularly implicated are the natural and simple or crude types such as calabashes earthen pots and low quality aluminium and other metal types.

Processing equipment

Mass production of food due to urbanization and technology advancement during the Industrial Revolution made possible the development of machines to do most of works hitherto undertaken by humans. Hence, there is less contact with food by humans and more contact with machines and equipment. Most machines and equipment are metallic though some parts may be made of rubber or plastic. Cardboard or paper may be used in boxes to hold harvested fruits or vegetables, or as packaging materials for bulk shipment and storage of various ingredients.

Metal processing equipment does not support the growth of microorganisms. Indeed it has no natural or normal microbial flora. However, food processing equipment has been claimed to be one of the major sources of contamination of foods. This is because most often very small food deposits or films are usually adhered to the surface of equipment no matter how thorough the cleaning and sanitation carried out. The films provide microenvironmens which favour survival, growth and development of microorganisms. Thus contamination is inevitable when food contacts the surfaces.

Ingredients

The use of ingredients in a processed food is very important because it enhances the taste and quality. Although ingredients may constitute a small part of the total food, they may add a substantial number of microorganisms. Thus, specifications, including acceptable microbiological levels, are required for the production and purchase of ingredients.

Spices or seasonings are often the source of high microbial numbers. Spices are derived from dried plant parts such as fruits, flower parts, leaves, buds, roots, bark or seeds, usually of tropical origin. These spices in addition to the fungal load, may contain over 10^8 aerobic bacteria per gram.

Also, they contain aerobic and anaerobic spores. The high microbial load statuses of spices and similar products have been documented (Banwart, 1980). Of particular concern is the microbial spectrum i.e. the kinds or species of microorganisms present in an ingredient, the point of cooking at which ingredients are introduced and the holding period before the food is consumed.

Food handlers

The microbial population on the hands and clothing of handlers generally reflects the environment and habits of individuals. The microorganisms may have been acquired from the environment e.g. soil, water, dust, etc. Other sources of the microorganisms include nasal cavities, mouth, skin and gastrointestinal tract. Species of microorganisms that had been found associated with the hands of food handlers include: *Bacillus, Pseudomonas, Sarcina, Peptococcus, Staphylococcus, Micrococcus, Alcaligenes and Corynebacterium*. The microorganisms may eventually contaminate food due to careless handling and through poor personal hygienic practices.

Product to Product

The handling of both cooked and raw foods together can result in the transfer of microorganisms from the raw to the finished product. This could result to a major health hazard if the cooked product is not given further treatment.

Others

Packaging materials, air, floor drains, etc.

Food Microbial Load and Spectrum

Mr. Vice Chancellor, Sir, another principal function of the food microbiologist is the determination of food microbiological quality which in simple term is the status of the microbial population (load) and the various species or kinds (spectrum) of microorganisms in given food sample.

Assessment of the microbiological population and spectrum is important for effective control of microorganisms not only in food but also in the environment and other products prone to microbial attack and growth. Microorganisms are frequently kept under control for several reasons under which include the following:

i. To minimize microbial Contamination and growth in food thus preventing increase in the disease causing and toxin producing microorganisms. This is to ensure that foods prepared in factories, restaurants and homes are safe and wholesome.
ii. To reduce the rate of deterioration or spoilage of food and similar products susceptible to microbial attack.
iii. To prevent the spread of diseases in hospitals, homes, schools, etc.
iv. To avoid contamination and deterioration in biotechnological procedures and products.

Microbial load and spectrum in food

Foods are basically of plant and animal origin. Thus, the characteristics of plant and animal tissues that affect the growth of microorganisms similarly affect the microbial load and spectrum in food. These factors or parameters may be categorized into two: (i) intrinsic and (ii) extrinsic parameters.

Microorganisms in food only grow if the food (environment) is suitable. If it (food) is not optimal, growth may occur at a lower rate or not at all, or they may even die depending on the species and conditions.

A brief consideration of the effects of these factors: water, temperature, pH, nutrient availability and availability of oxygen in the food environment on microbial load and spectrum is important.

Water

Over 80% of the body mass of microorganisms is water and during growth, nutrients and waste products enter and leave the cell, respectively, in solution. This suggests that microorganisms can grow in or on food or other suitable materials including living hosts which have adequate free water.

There are documentations (Banwart, 1980; James, 1992) on how to define availability of water to microorganisms and indeed to other biological systems. These include: equilibrium relative humidity (RH), water potential – expressed in units of pascals and water activity. In the food industry, the term water activity (a_w) is applied; and this is now commonly adopted by scientists across disciplines worldwide. Water activity is directly equivalent to equilibrium relative humidity (RH) but ranges from 1.0 (pure water) to zero (no available water). Qualitatively, a_w is a measure of unbound free water in a system available to support biological and chemical reactions. Water activity is not absolute water content. Two foods with the same water content can have very different a_w values depending upon the degree to which the water is free or otherwise bound to food constituents.

Microorganisms vary widely in their response to water availability with the moulds and yeasts generally more tolerant to water stress than the bacteria (James, 1992; Adebajo *et al.*, 1994). For example, whereas many fungi can

grow satisfactorily in or on foods with a_w levels near 0.85, only a few specialized bacteria are able to grow minimally at a_w levels below 0.9 (Table 2.2). Thus, bacteria generally predominate, in counts and kinds in foods with a_w levels approaching 1.00 when compared to the yeasts and moulds which are able to grow and multiply in foods having comparatively reduced a_w levels (James, 1992). In general, though with some exceptions, it can be summarized that the a_w level requirements of bacteria > yeasts > moulds (Tables 2.2 and 2.3). Research findings have shown that the more unfavourable the a_w of a food sample, the greater the delay (lag) in initiation of growth or germination of spores. This fact is of immense practical significance in food preservation technology.

Table 2.1: Important genera of bacteria, moulds and yeasts associated with foods

	Bacteria	
Acinetobacter	*Enterbacter*	*Pediococcus*
Aeromonas	*Erwinia*	*Proteus*
Alcaligenes	*Escherichia*	*Pseudomonas*
Alteromonas	*Flavobacterium*	*Psychrobacter*
Bacillus	*Hafnia*	*Salmonella*
Brochothrix	*Lactococcus*	*Serratia*
Campylobacter	*Lactobacillus*	*Shewanella*
Carnobacterium	*Leuconostoc*	*Shigella*
Citrobacter	*Listeria*	*Staphylococcus*
Clostridium	*Micrococcus*	*Vagococcus*
Corynebacterium	*Moraxella*	*Vibrio*
Enterococcus	*Pantoea*	*Yersinia*
	Moulds	
Alternaria	*Cladosporium*	*Mucor*
Aspergillus	*Colletotrichum*	*Penicillium*
Aureobasidium	*Fusarium*	*Rhizopus*
Botrytis	*Geotrichum*	*Trichothecium*

Byssochlamys	*Monillia*	*Xeromyces*
	Yeasts	
Brettanomyces	*Issatchenkia*	*Schizosaccharomyces*
Candida	*Kluyveromyces*	*Tolulaspora*
Cryptococcus	*Pichia*	*Trichosporon*
Debaryomyces	*Rhodotorula*	*Zygosaccharomyces*
Hanseniaspora	*Saccharomyces*	

Source: James (1992)

Table 2.2: Approximate Minimum a_w Values for Growth of Microorganisms Important in Foods.

Organisms	a_w	Organisms	a_w
Groups		**Groups**	
Most spoilage bacteria	0.9	Halophillic bacteria	0.75
Most spoilage yeasts	0.88	Xerophillic molds	0.61
Most spoilage molds	0.80	Osmophillic yeasts	0.61
Specific Organisms		**Specific Organisms**	
Clostridium botulinum, type E	*0.97*	*Candida Scottii*	*0.92*
Pseudomonas spp.	*0.97*	*Trichosporon pullulans*	*0.91*
Acinetobacter spp.	*0.96*	*Candida zeylanoides*	*0.90*
Escherichia coli	*0.96*	*Staphylococus aureus*	*0.86*
Enterobacter aerogenes	*0.95*	*Alternaria citri*	*0.84*
Bacillus subtilis	*0.95*	*Penicillum patulum*	*0.81*
Clostridium botulinum,		*Aspergillus glaucus*[a]	*0.70*
Types A and B	*0.94*	*Aspergillus conicus*	*0.70*
Candida utilis	*0.94*	*Aspergillus echinulatus*	*0.64*
Vibrio parahaemolyticus	*0.94*	*Zygosaccharomyces rouxii*	*0.62*
Botrytis cinerea	*0.93*	*Xeromyces bisporus*	*0.61*
Rhizopus stolonifer	*0.93*		
Mucor spinosus	*0.93*		

Adapted from: Banwart (1980) and James (1992).

Table 2.3: Approximate Minimum Water Activity Tolerated by Microorganisms

Organisms Group	a_w
Most spoilage bacteria	0.9
Most spoilage yeasts	0.88
Most spoilage moulds	0.80
Halophilic bacteria	0.75
Xerophilic moulds	0.61
Osmophilic yeasts	0.61

Adapted from: Banwart (1980) and James (1992).

Temperature

The microbial population and species associated with food are also influenced by the ambient or storage temperature. A given species of microorganism grows and reproduces most rapidly at a specific temperature: the optimum growth temperature. Outside the optimum growth temperature, the rate of growth tails off as the temperatures increase or decrease from the optimum. Thus, there is maximum and minimum temperature beyond which growth will not occur. For all foods, the storage temperature will directly affect the species and total counts of microorganisms that will be associated with the food.

pH

Generally, most bacteria, yeasts and moulds grow best at or near pH7 (6.6 – 7.5) while few grow below 4.0. The approximate pH growth ranges of some major foodborne organisms are well known and adequately documental (Banwat, 1980; James, 1992) and are illustrated in Fig 2.1. The information presented in the figure can be used to predict the microbial count and or species expected to be associated with a given food sample and such is vital in food preservation technology.

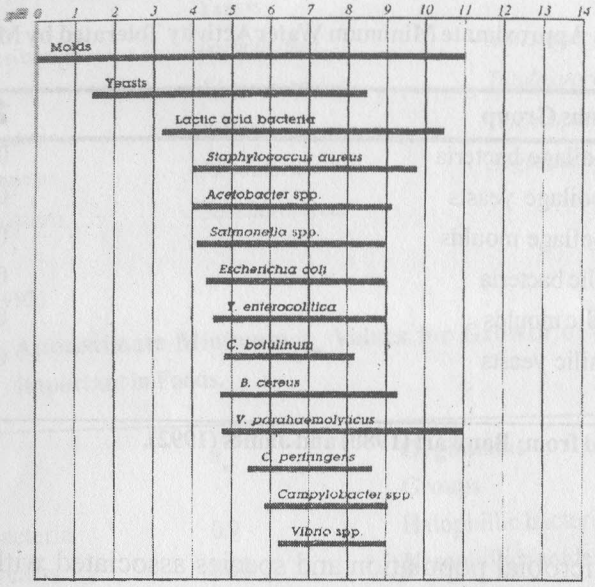

Fig. 2.1 Approximate pH growth ranges for some Foodborne organisms.
Source: Willey *et al.* (2011)

3. DETRIMENTAL ASPECTS OF MICROORGANISMS IN FOOD

It is a general knowledge that some hazards are associated with foods. Attempts had been made by some researchers (Banwart, 1980; James, 1992) to classify such hazards. At least six principal categories are considered to be very important and they include the following:

i. Microbiological hazards
ii. Malnutrition hazards
iii. Hazards of environmental contaminant
iv. Hazards of naturally occurring toxins
v. Hazards of pesticides and other agro-chemicals
vi. Hazards of conscious food additives

Mr. Vice Chancellor, Sir, the numerous data available especially in the technologically advanced nations where there is proper documentation, microbiological hazards of food are by far the most important (CDC, 2006).

The hazards due to microorganisms in food can be considered under two broad categories:

i. Foodborne diseases (infections and intoxications or poisonings)
ii. Deterioration and spoilage of food resulting in economic losses.

Deterioration and Spoilage of foods

Food deterioration and spoilage are caused by several factors including the following: (a) growth and activities of microorganisms, (b) activities of natural food enzymes, (c) insects, parasites and rodents (d) temperature (e) moisture and dryness (f) air (g) light (h) time.

A sample of food may be regarded as spoiled when it has been damaged or injured so as to make it undesirable for human consumption. The overall significance of food deterioration and spoilage is that they deprive man of the much needed food especially in the developing countries where food is in short supply. It has therefore became mandatory to put in place all necessary control measures to prevent food spoilage or at list drastically reduce it.

Microbial Foodborne Diseases

Most of the familiar foodborne diseases that are contracted from foods by humans are frequently due to bacterial or viral agents (James 1992; Vasickova *et al.*, 2005). However, to the general public, bacteria are the most important of the two groups. Thus, most processing and handling precautions are primarily directed against them (Varnam and Evans, 1991). The bacterial and viral foodborne diseases are usually more frequent and also assumed to be more important than those due to fungal agents because the incubation time of most of the diseases is between 1hr and 72hr thus causing their symptoms to manifest quickly. This is however not so for the food diseases due to moulds of which the metabolites or mycotoxins are frequently consumed in small quantities in food or feed. Smith and Hacking (1983) reported that the effects of continued low-level mycotoxin consumption in food or feed are variable, undramatic and not easily recognized. Tables 3.1. and 3.2. summarize the major facts on bacterial, and mould-associated foodborne diseases.

Table 3.1 Summary of bacterial foodborne diseases

Causative agent	Incubation time (hours)	Clinical features	Duration of illness
Salmonellae (usually *Salmonella Typhimurium)*	6-72	Diarrhoea, abdominal pain, vomiting, and fever	Several days; up to 3 weeks
Staphylococcus aureus	1-6 (usually 2-4)	Nausea, vomiting, abdominal pain, prostration, dehydration, and subnormal temperatures	1-2 days
Clostridium perfringens	8-22 (usually 12-18)	Diarrhoea and abdominal pain. Vomiting is rare	1-2 days
Clostridium botulinum	12-96 (usually 18-36)	Dizziness, headache, tiredness double vision, accompanied by Dryness of the mouth and throat, Followed by an inability to speak due to paralysis of the throat muscles. Death often occurs as a result of paralysis of the respiratory centres.	3-7 days in fatal cases. Otherwise months or years to recovery.
Bacillus cereus	6-16 (classical outbreaks)1-6	Acute diarrhea and occasional vomiting. An acute attack of nausea and vomiting with some diarrhea.	Generally no longer than 24 hours
Escherichia coli	12-72 (usually 12-24)	Abdominal pain, fever, vomiting, and diarrhea that may be prolonged with blood and mucus in the stools.	3-5 days
Vibrio parahaemolyticus	12-24	Abdominal pain, vomiting and diarrhoea, leading to dehydration and fever.	1-7 days
Campylobacter species	72-120	Fever, followed by persistent diarrhoea with foul-smelling and often bile-stained stools.	1-10 days

Source: Jacob (1989)

Table: 3.2 Mycotoxicoses commonly associated with humans.

Disease	Substrate	Etiologic agent
Alimentary toxic aleukia	Cereal grains (toxic bread)	*Fusarium sporotrichoides*
(ATA) or Septic Angina	Fodder (skin contact,inhaled	*Dendrodochium toxicum*
Dendrodochiotoxicosis	fodder particles)	
Kashin Beck disease 'Urov	Cereal grains	*Fusarium sporotrichiella*
disease'		*Stachybotrys atra*
Stachybotryotoxicosis	Hay, cereal grains, fodder (skin contact, inhaled haydust)	
Cardiac beriberi	Rice	*Fusarium*
Ergotism	Rye, cereal grains	*Claviceps purpurea*
Balkan nephropathy	Cereal grains	*Penicillium*
Reye's syndrome	Cereal grains	*Aspergillus*
Hepatocarcinoma	Cereal grains, groundnuts	*Aspergillus*
Pink rot	Celery	*Selerotinia sclerotiorium*
Onyalai	Millet	*Phoma sorghina*

Adapted from: Banwart (1980) and James (1992).

Mr. Vice Chancellor, Sir, the keen interest of this lecturer and his collaborators (Adebajo and Oyesiku; 1994, Adebajo and Idowu; 1994, Adebajo, 2000, Adebajo and Diyaolu, 2003), over the years on some food snacks and masticatories is not accidental. It was borne out of deep concern for the dangers posed to people who constantly and ignorantly consume stale samples of suspect foods and mastocatories which in later years may result in problematic mycotoxicoses. Unfortunately however, by the time the health problems resulting from such unwholesome consumption of stale implicated foods will manifest it may be virtually impossible for consumers to link the disease with their favourable food snacks. Consequently they may take to superstition and wrong accusations of family members, neighbours and even close associates as been responsible for their strange diseased conditions.

Our researches centered on foods such as tiger nuts, donkwa, corn powder snack, corn cake, kolanuts (*Cola acuminata* and *C. nitida*) and *Garcinia cola*. Without exception, they all have low water activity levels and thus, moisture would not readily be available to the associated microorganisms. Hence, moulds are the most favoured biodeteriogens or spoilage agents. Under such low levels a_w the normal growth of the associated moulds will be restricted and the intermediates of the primary metabolic pathways are not used for growth, but are 'shunted' or diverted into a range of unusual pathways. This has been well explained and illustrated by Deacon (1980) and Russell *et al*. (2007). This is the phase of secondary metabolism when products such as mycotoxins and antibiotics are produced.

However, because the food types in question have peculiar strong taste which may be sweet, bitter, peppery, etc., it may not be easy for the consumers to notice the presence of the secondary metabolites especially the mycotoxins. Thus there is unrestricted and unconscious or unintention consumption of mycotoxins contaminated food products.

According to Adebajo (1993a), this problem of ingesting contaminated product is aggravated by the sweet taste which encourages the consumption of even the conspicuously mouldy samples by the less discriminatory children.

The children's conception about food is "if it is sweet, it is good and safe" However we know that this is not always true.

4. TIGER NUTS: THE PROSPECTS AND PROBLEMS

The washed and sun-dried tubers of *Cyperus esculentus* Linn are among the popular, cheap and sweet convenience foods in West Africa (Adebajo, 1993a). They are also called rootstock snacks, earth almonds, rush nuts, Brazil nuts, chufa and Zulu nuts (Adebajo and Oyesiku, 1994; Adejuyitan, 2011). In recent time, several researchers (Ade-Omowaye *et al*., 2008; Sanful, 2009; Adejuyitan, *et al*., 2009) have reported on the economic potentials and health benefits of this underutilized crop. It is reported to be high in dietary fibre content, which could be effective in the treatment and prevention of many diseases including colon cancer, coronary heart diseases, obesity, diabetics and gastrointestinal disorders (Anderson *et al.,* 1994).

The tubers are also reported to be aphrodisiac carminative, diuretic, emmanogogue, stimulant and tonic (Chopra *et al*; 1986). The same tubers have also been reported by Chevallier (1996) to be used in the treatment of flatulence, indigestion, diarrhea, dysentery and excessive thirst.

Conversely, our findings (Adebajo 1993a; Adebajo and Oyesiku, 1994) on the microflora and mycotoxin content of retail samples of the same tubers suggest that more investigations have to be conducted in order to properly understand the microbiological quality and safety of the tubers and how best to handle them during cultivation, processing and storage. Our research findings are presented below:

The mean moisture contents and pH of the rootstock snack samples during storage are illustrated in Fig 4.1. While the moisture levels increased with time, the pH declined during the same period. This trend in increasing moisture contents suggests that the ambient relative humidity was higher than that corresponding to the water activity () of the snack (James, 1992), thus moisture was absorbed by the latter. This had a far reaching affect on the micoflora of the snack. Initially the moisture contents ranged between 10.5 and 13.8% and thus mostly within limits safe for storage (Banwart, 1980). The of most of the samples were thus too low

for the germination of spores and growth of most microorganisms including the storage moulds. Absorption of moisture from the humid environment with time of storage increased the to a level which at first permitted mainly the growth and activities of the primary mould deteriogens. As the further increased due to subsequent moisture absorption and the metabolic activities of the early colonizers, the incidence and, thus activities of the moulds increased (Table 4.1.). It is this increase in microbial activities in stored products especially carbohydrate-based substrates that caused the drop in pH with time (James, 1992) related to the organic acids produced during microbial metabolism (Ogundero,1981). Consequently, maintaining low moisture content of the snack is mandatory for effective control of microbes and their associated problems.

Table 4.1. summarizes the incidence of fungal contamination of the snack samples during the storage. At first, the rates were low (0.8-25%) but later these became high (5-97% at 150 days) suggesting a corresponding increase in the accumulation of the toxic secondary metabolites in the substrate. These results followed the moisture content trend (Figs 4.1 and 4.2) and are of public health significance most especially in West Africa where the control, regulation and inspection of food products offered for sale are seldom undertaken and the populace, due to poverty, is poorly discriminating in the choice of foods they consume. Furthermore, the case with which mouldy samples of this snack are adulterated and represented to the unsuspecting consumers as fresh is of concern, requiring immediate attention.

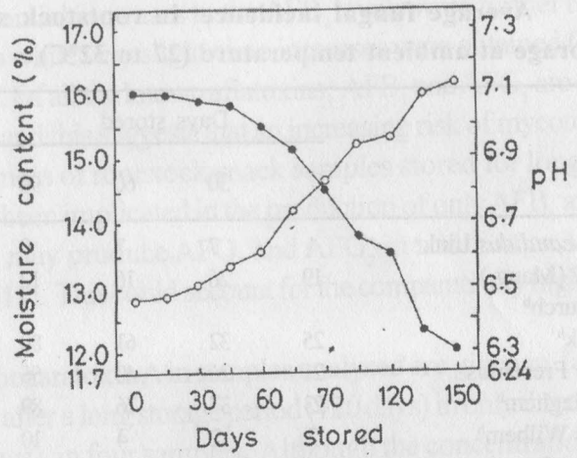

Fig.4.1 Mean moisture contents(O) and pH (●) of rootstock snack samples (25) during storage at ambient temperature (27–32 °C).

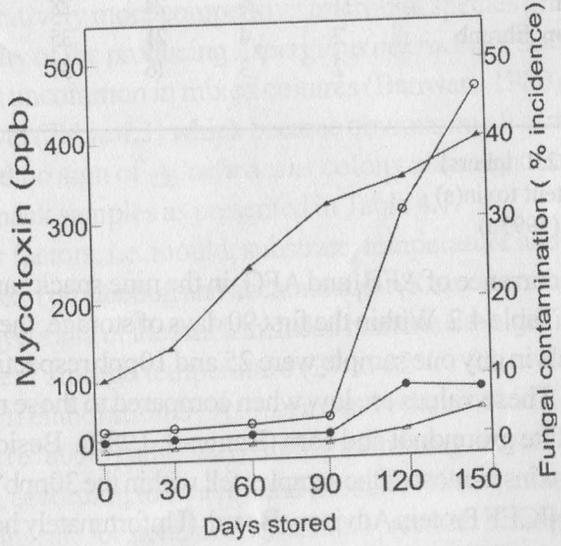

Fig. 4.2 Fungal incidence (▲) and levels of aflatoxim B_1 (O) aflatoxim G_1(●) and ochratoxim A (△) in rootstock snack samples during storage at ambient temperature (27 to 32°C)

Table 4.1 Average fungal incidence[a] in rootstock snack samples (25) during storage at ambient temperature (27 to 32°C)

Fungus	Days stored					
	0	30	60	90	120	150
Aspergillus candidus Link[b]	4	7	7	9	12	17
A chevalieri (Mang.) Thom & Church[b]	19	26	16	12	5	5
A flavus Link[b]	25	32	61	80	85	89
A fumigates Fresenius[b]	21	26	40	56	59	67
A niger v. Tieghem[b]	23	37	76	89	94	97
A ochraceus Wilhem[b]	2	2	4	10	12	15
A parasiticus Spear[b]	9	11	12	17	21	27
Fusarium moniliforme Sheldon[b]	0.8	2	2	2	6	5
Penicillium chrysogenum Thom[b]	12	16	21	32	35	41
P. citrinum Thom[b]	11	26	24	28	33	36
Rhizopus nigrians Ehrenb	2	4	21	35	48	36
Rhizopus sp.	2	3	16	31	37	41

[a] Isolation % (of 250 tubers).
[b] Producer of potent toxin(s)
Source: Adebajo (1993a)

The occurrence of AFB_1 and AFG_1 in the nine snack samples analyzed is summarized in Table 4.2 Within the first 90 days of storage, the maximum AFB_1 and AFG_1 levels in any one sample were 25 and 10ppb respectively recorded for sample No 21. These values are low when compared to those recorded for other food products like groundnut and corn (Banwart, 1980). Besides, the aggregate of the two aflatoxins in most of the samples fell within the 30ppb 'safe' guideline of FAO/WHO/UNICEF Protein Advisory Board. (Unfortunately however, the cheap snack is often taken in large quantities by the consumers who are mostly of poor nutritional status and thus likely to be readily susceptible to mycotoxins. On the 120th day, the levels of the two toxins had increased significantly and these ranged from 95 to 460 ppb and from 40 to 125 ppb, for AFB_1 and AFG_1 respectively.

By the 150th day, substantial increases in the AFB_1 levels were further recorded for all the nine samples while very slight or no increases were obtained for AFG_1 during the same period. Of all the known aflatoxins, AFB_1 and AFG_1 are the most toxic (Banwart, 1980) and this suggests that an increasing risk of mycotoxicoses is posed to the consumers of rootstock snack samples stored for long period. *Aspergillus flavus* has been implicated in the production of only AFB_1 and AFB_2 while A. *parasiticus* may produce AFG_1 and AFG_2 in addition to AFB_1 and AFG_2 (Willey *et al.*, 2011). This could account for the comparatively higher levels of AFB_1 over AFG_1.

The levels of ocharatoxin A in samples analysed are given in Table 4.3.. The toxin wa detected after a long storage period (120 days) in only three samples and later (after 150 days), in four samples. Although the concentrations of the toxin in the snack samples were very low, notwithstanding, its presence indicates the suitability of the substrate for the elaboration of the toxin. It is possible that the presence of comparatively more competitive microbial species greatly retarded the elaborating ability of the producing *Aspergillus ochraceus*. Such associative growth effect is not uncommon in mixed cultures (Banwart, 1980). Indeed, the visible mould growth (Table 4.3) which became obvious on all samples as from the 90th day showed no sign of A. *ochraceus* colony although the species was isolated from the snack samples as presented in Table 4.1.

Four major factors, i.e. mould, substrate, temperature and moisture are essential in mycotoxin production and accumulation (Russell *et al.*, 2007) In the present study, the mycoflora of the snack included numerous toxigenic fungi (Table 4.1) and the ambient storage temperature (27 to 32°C) fell within the range conducive for toxin elaboration by A. *flavus* and other moulds. The ambient relative humidities (e"80%) particularly during the raining season in the south of West Africa could, according to (Davey and Elcoate, (1965), raise the moisture levels above the limits safe for storage of agricultural produce. Finally, the rootstock snack is a suitable substrate for production of AFB_1, AFG_1, ochratoxin and presumably, for other related mycotoxins.

Perhaps the most crucial of the four factors, due to the relative ease with which it could be regulated, is the moisture content. Consequently, storage of

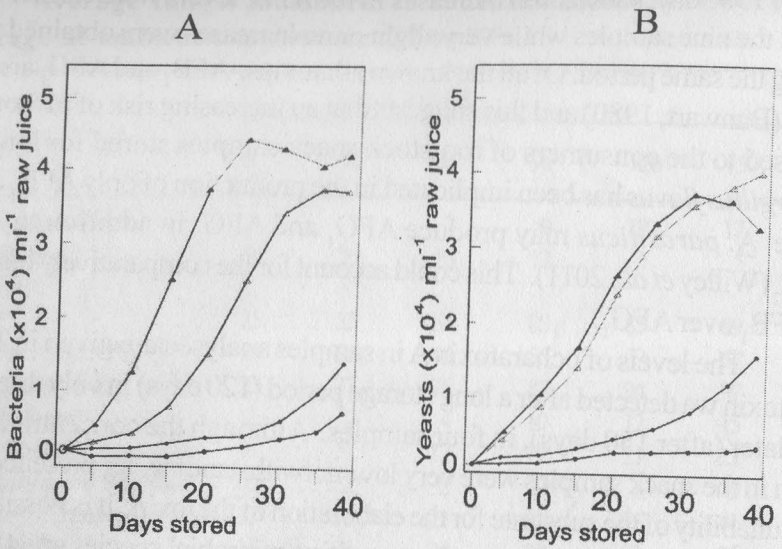

Fig: 4.3 Microbial populations in raw juice extracted from the tubers of *Cyperus esculentus* During storage of different temperature. Each point is an average of 25 determinations.
Source: Adebajo (1993b)

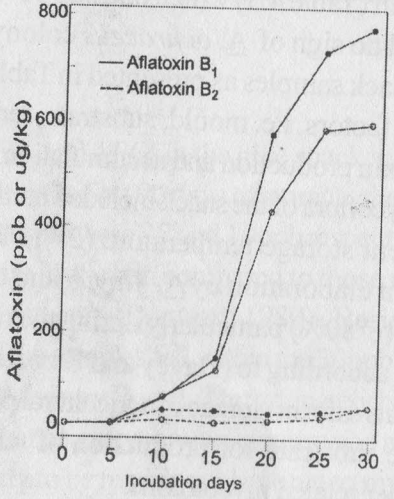

Fig: 4.4 Production of aflatoxins by *Aspergillus flavus* in milled nuts of *Cola acumminata* (O) and C.nitida (●) at 30°C, Each point is a mean of five deterninations.
Source: Adebajo, (2000)

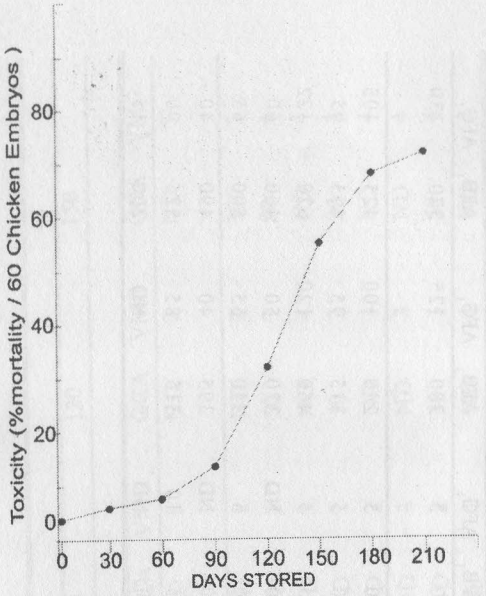

Fig: 4.5 Relaticve toxicity of extracts from rootstock snack samples stored at room temepreature (27-32°C)
Source: Adebajo and Oyesiku (1994)

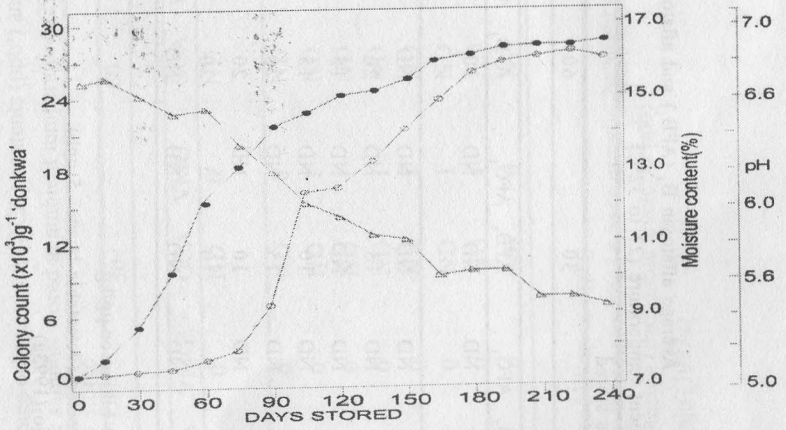

Fig: 4.6 Total mould colony counts (O), moisture contents (● and pH s(Δ) of 'donkwa' snack with time of storage. Each point is an average of values obtained for 50 samples separately stored in raffia snacks at room temperature.
Source: Adebajo and Idowu (1994)

Table: 4. 2 Average aflatoxin B_1 (AFB_1) and aflatoxin G_1 (AFG_1) contents (ppb[a]) in rootstock snack samples stored at ambient temperature (27 to 32°C)

Sample	Days stored											
No.	0		30		60		90		120		150	
	AFB_1	AFG_1	AFB_1	AFG_1	AFB_1	AFG_1	AFB_1	AFG_1	AFB_1	AFG_1	AFB_1	AFG_1
1	ND[b]	ND	ND	ND	10	ND	20	5	280	125	370	130
3	ND	ND	ND	ND	ND	ND	20	5	240	100	425	105
6	10	ND	15	ND	20	ND	20	5	315	95	495	95
9	ND	ND	ND	ND	15	5	25	5	460	120	620	122
12	ND	ND	10	ND	15	ND	20	ND	320	50	460	60
15	10	ND	15	ND	20	ND	20	5	340	65	500	65
18	ND	ND	10	ND	20	ND	30	ND	395	40	490	40
21	10	5	10	5	20	5	25	10	315	85	525	90
24	ND	ND	ND	ND	ND	ND	ND	ND	95	ND	200	15

[a] ppb=parts per billion or µg/kg.

[b] ND= Not detected (detectable levele" 5 ppb).

Source: Adebajo (1993a)

Table: 4.3 Average ochratoxin A (OCA) contents (ppb[a]) and the visible mold growth (VMG[b]) ratings recoeded for rootstock snack samples stored at ambient temperature (27 to 32°C)

Sample	Days stored											
No.	0		30		60		90		120		150	
	OCA	VMG[b]	OCA	VMG	OCA	VMG	OCA	VMG	OCA	VMG	OCA	VMG
1	ND[c]	0	ND	0	ND	0	ND	1	ND	2	ND	3
3	ND	0	ND	0	ND	0	ND	1	ND	2	30	3
6	ND	0	ND	1	ND	1	ND	2	50	3	80	4
9	ND	0	ND	1	ND	2	ND	3	ND	4	ND	4
12	ND	0	ND	1	ND	1	ND	2	10	3	30	3
15	ND	0	ND	1	ND	1	ND	2	ND	3	ND	4
18	ND	0	ND	1	ND	2	ND	3	ND	3	ND	4
21	ND	0	ND	1	ND	1	ND	2	40	3	50	4
24	ND	0	ND	0	ND	1	ND	1	ND	1	ND	2

[a] ppb=parts per billion or µg/kg.

[b] VMG rating: 0= no growth; 1= trace growth; 2= slight growth; 3= moderate growth; 4= abundant growth.

[c] ND= Not detected (detectable levele" 5 ppb).

Source: Adebajo (1993a)

rootstock snack under conditions that would allow very little or no moisture absorption; and adoption of strict control measures to discourage adulteration and representation of mouldy samples for sale, would ameliorate the potential hazards posed to the health of the consumers.

Other research studies conducted on similar stored products (i.e tiger nuts, kola nuts and donkwa) yielded basically similar findings. The highlights of the result are illustrated in Figures 4.3 through 4.6

5. BENEFITS AND CONTROL OF MICROORGANISMS IN FOOD

Mr. Vice Chancellor, Sir, a pertinent question to ask at this juncture is: Are all microorganisms in food hazardous, injurious or non beneficial? Better still, let me make it open and general: Are all microorganisms bad? The answer is straight forward: No.

Not all microorganisms are bad or harmful; this is also true for the microorganisms in food. Some microorganisms facilitate the production or are actively used in the food industry to produce foods such as cheese, yoghurt, chocolate, ogi, coffee, sauerkraut, soy sauce, tempeh, etc. Some examples of fermented foods produced from fruits, vegetables and beans, and the microorganisms involved in the fermentation are presented in Table 5.1.

TABLE: 5.1 Fermented Foods Production from Fruits, Vegetables, Beans And Related Substrates

Foods	*Raw Ingredients*	*Fermenting Microorganisms*	*Area*
Coffee	*Coofee beans*	*Erwinia dissolvens, saccharomyces spp.*	Brazil Cong Hawaii, India
Gari	*Cassava*	*Corynebacterium manihot, geotrichum spp.*	West African
Kenkey	*Corm*	*Aspergillus* spp., *Penicillium* spp., Lactobacilli, *yeasts*	Ghana, Nigeria
Kimchi	*Cabbage and other begetables*	Lactic acid bacteria	Korea
Miso	Soybeans	*Aspergillus oryzae, Zygosaccharomyces rouxii*	Japan
Ogi	*corn*	*Lactobacillus plantarum, Lactococcus lactis, Zygosaccharomyces rouxii*	Nigeria
Olives	*Green olives*	*Leuconostoc Mesenteroides, lactobacillus plantarum*	Worldwide
Ontjom	*Peanut presscake*	*Neurospora sitophila*	Indonesia
Peujeum	Cassava	moulds	Indonesia
Pickles	Cucumbers	*Pediococcus cerevisiae, lactobacillus plantarum*	Worldwide
Poi	Taro roots	lactic acid bacteria	Hawaii
Sauerkraut	Cabbage	*L. mesenteroides, L. plantarum, L. brevis*	Worldwide
Soy sauce	Soybeans	*Aspergillus oryzae or A. soyae, Z. rouxii, Lactobacillus delbruekii*	Japan
Sufu	Soybeans	*Actinimucor elegans, Mucor* spp.	China
Tao-si	soybeans	*A. oryzae*	Philippines
Tempeh	Soybeans	*Rhizopus oligosporus, R. oryzae*	Indonesia, new Guinea, Surinam

Adapted from: James (1992) and Dubey (2006).

Apart from their application in food fermentations, microorganisms can be used directly as food and food amendments. They can also be used to produce useful tangible products and services. Tables 5.2 and 5.3 illustrate the different useful microbial products produced by activities of some bacteria and fungi, respectively.

The services for which humans engage microorganisms include: applying them for the cleaning up of polluted environment (i.e. for bioremediation), using them as agents for biocontrol to completely eliminate or reduce drastically the troublesome organisms such as weeds, insect pests, rodents, birds, vectors of diseases and even disease causing and toxin producing microorganisms in our

environment. They can also be used beneficially as reagents in analytical procedures in modern advanced biotechnology.

Unfortunately, however, the same microorganisms, in the hand of bioterrorists could be turned into weapon of mass destruction. This is despicable, very low and negative biocontrol. The United Nations is totally against such wicked application and it is expected that all scientist and governments throughout the universe should neither engage nor support such antihuman technology.

As previously highlighted in the course of this lecture, microorganisms can be a nuisance, or even dangerous, in many everyday situations and they therefore need to be controlled either by eliminating them completely or by inhibiting their activities. Another alternative is to avoid them or adopt strategies that will make it difficult for the microorganisms to grow, multiply and contaminate us or our products.

Table: 5.2 Microorganisms (bacteria) and their Products

Name of Organism	Microbial products: Primary Metabolites	Secondary metabolites	Enzymes	Others
	(1)	(2)	(3)	(4)
Acetobacter aceti	Acetic acid	-	-	-
Acetobacterium woodii	Acetic acid	-	-	-
Bacillus brevis	-	Gramicidin	-	-
B. polumyxa	-	Polymyxin B	Amylase	-
B. popilliae	-	Endotoxin	-	-
B. subtilis	-	Bacitracin	-	-
B. thuringiensis	-	Endotoxin	-	-
Clostridium aceticum	Acetic acid	-	-	-
Gluconobacter	-	-	-	-
Suboxidans	Vinegar	-	-	-
Methylophus				
methylophus	Glutanis	-	-	-
Pseudomonas				
denitrificans	Vitamin B12	-	-	yoghurt
micromonospora				
purpurea	-	Gentamicin	-	-
Nocardia mediterranei		Rifarycin	-	-
Stretomyces				
Aureofaciens	-	Tetracycline	-	-
S. tradiae	-	Neomycin	-	-
S. griseus	-	Streptomycin	-	-
S. noursei	-	Nystain	-	-

Source: Dubey (2006) (SCP= Single Cell Protein

Table: 5.3 **Microorganisms (fungi) and their Products**

Microbial products				
	Primary Metabolites	Secondary metabolites	Enzymes	Others
	(1)	(2)	(3)	(4)
Aspergillus niger	-	Citric acid	-	-
A.oryzae	-	-	*Amylase,*	*SCP*
Candida lipolytica	-	-	*Cellulose*	*Soya sauce*
			Amylase	
C. utilis	-	-	*Lipase*	*soya sauce*
Cephalosporium				
acremopnium	-	Cephalosporin	-	-
fusarium				
moniliforme	-	-	-	*SCP*
gibberella				
fujikuroi	-	Gibberellin	-	-
Morchella esculenta	-	-	-	*SCP*
Penicillium				
Chrysogenum	-	Penicillin	-	-
Rhizopus arrihizus,	-			
R. nigricans	-	Steroides	-	-
Saccharomyces				
Cerevisiae	Ethanol	-	-	SCP, wine,
S. lipolytica	Citric acid	-	-	*SCP*
Trichoderma	-	-	-	-
Harzianum,	-	-	Cellulase	-

Different strategies for the control and destruction of microorganisms are now being applied by man. Such methods have been well documented (Efuntoye , 1999; Bankole and Adebanjo 2003; Adebanjo, 2004; Willey *et al.* 2011) and the goal is twofold: (i) to destroy pathogens and prevent their transmission, and (ii) to reduce or eliminate microorganisms responsible for the contamination of water, food, and other substances.

Perhaps, a simple, practicable, effective, multipurpose and free microbial control strategy for ensuring food safety has been published by WHO (2004). It is reproduced below:

WHO 5-KEY STRATEGY FOR ENSURING FOOD SAFETY (WHO, 2004)

1. Keep hands and cooking surface clean.
2. Separate raw and cooked foods
3. Cook food thoroughly
4. Keep stored food at safe temperatures
5. Use safe water and raw ingredients

6. CONCLUSION

Mr. Vice Chancellor Sir, distinguished ladies and gentlemen, it is an important fact that microorganisms will continue to be associated with our foods and similar products whatever the precautions and safety practices adopted during the cultivation harvesting processing and storage.

Some of the microorganisms that contaminate our food may cause infections and even intoxications depending on the species and the ambient environmental conditions of storage. Other microorganisms may bring about deterioration and eventually spoilage, thus resulting in loss of the much needed food. The economic wastage due to spoilage is a major problem in our developing economy which definitely, for several obvious reasons, cannot continue to bear such heavy burden.

Consequently, the government has to play the leading role by adequately funding appropriate agricultural projects and schemes with the ultimate aim of achieving nationall food security.

The governments at all levels must also address the issue of education and training of farmers and all other groups that will be involved in the food business.

The use of mass media, electronic and print, to provide appropriate mass education to the general public will go a along way to inculcate the behavioural changes and right attitude necessary for food microbiological quality and safety.

Prompt drying of agricultural products and storage under conditions that will minimize moisture absorption by produce is perhaps one of the easiest and most practicable approaches for reducing losses due to microbial activities

ACKNOWLEDGMENTS

Foremost, I give thanks to our Heavenly Father, the Almighty God, for making this day possible and most especially for saving my life miraculously on Friday, 12th of this month when I was travelling from Oru to Ijebu-Ode to collect the invitation cards for today's event. To Him be glory, honour, praise and adoration for ever and ever.

I am grateful to my late father Pa. Julius Babafemi Adebajo who departed from this Earth in May this year. For his total support to my education and for his encouragement always. My late mother, Mrs. Felicia Adebajo for her love, unflishing support and total commitment to my success and achievement. I am so lucky to have been born by the best parents in the world.

Sincere gratitude goes to my late maternal grand-mother, Mrs. Salamotu Sanni for her kindness and support without restriction. I also give special thanks to my late uncle, the former principal of Ijebu Musilim College, Alhaji A.O. Sanni and Mama, Mrs. A. Sanni for the care and love they showered on me during the period I lived with them. Mama you will live the rest of yourlife in good health and joy. Amen. And may all your children and children children never lack peace and good things of life. Amen.

I thank all my sisters and brothers for their love, support and a good harmonious family life. May it please the Lord to keep the enviable family bond

between us and make it to wax stronger in Jesus' name. Amen. All my in laws are appreciated. Mr. Felix Adenaike, Mr. Ayo Adelaja, the Adekoya's and so many more that I may not include the name, I gratefully appreciate you.

My particular thanks go to all my uncles, aunts, cousins, nephews and nieces. Also my neighbours in Ilaporu, Ijebu-Ode and other places of my abode, you have all been good and peaceful neighbours. I specially appreciate all the landlords and their families (NELASS), Ilaporu, for their good neighbourliness and love.

I thank all my friends, study and play mates every where and colleagues from other Universities, Research Institutes and other Educational Institutions present here today.

I will forever appreciate and thank all my teachers at the St. Saviour's Primary School and Adeola Odutola College both in Ijebju-Ode and the one and only premier university, University of Ibadan. I am highly delighted to have the privilege of attending such distinguished schools and university.

As for my set in Adeola Odutola College 69/73 family, I am indeed grateful for the five happy years we spent together and for the continued friendship and love we are still sharing together. And all other members of AOCOSA here present, I thank you for coming. I am also especially thankful for all the students: taught at Ijebu-Ode Grammar School and Ogun State College of Education (now Tai Solarin College of Education) and also those that graduated from this great University. Thanks for coming. You will also be honoured. Amen.

My particular thanks and deep appreciation go to my supervisor, Prof. V. W. Ogundero who effectively supervised my research studies for the M.Sc and Ph.D programmes in University of Ibadan. Thank you Sir. And may the goodness and mercy continue to be your portion and all your children's portion Amen.

I express my gratitude to the Management and Staff of the Nigerian Stored Products Research Institute, Onireke, Ibadan for allowing unrestricted use of facilities in their laboratories. Particular mention must be made of Rev. J. S. Opadokun, Messrs J. N. Ikeorah and F. M. Afolabi for their immense contributions to the development of my research skill especially the mycotoxin assays. I also remember with thanks Dr. Adeyemi Joshua, the former Director of Federal Seeds

services, Ibadan for his assistance each time I made request for seed samples and some other research items.

My special thanks also go to Prof. and Mrs. F. A. Adeyemi and Honourable and Barrister (Mrs.) Banwo for your kindness, warmth, love and your endless effort to ensure that I achieve success in all areas of life. May God continue to be with you and bless your children abundantly. Amen.

I joined this University in 1985. Since then I have enjoyed good and joyful relationship with all the staff I had worked with. Indeed, I used to refer to myself as an 'inverse paranoid' in Olabisi Onabanjo University because it appears that all the members of staff have conspired to treat me good always.

I wish to specially thank Professor Afolabi Soyode, the then Vice Chancellor and his DVC, Professor Odutola Osilesi during whose tenure I was promoted to the rank of a Professor.

Similarly, I wish to specially congratulate and thank the incumbent Vice Chancellor, Professor Saburi Adejimi Adesanya and the DVC, Professor Adewale Okanlawon Sule-Odu for the unique opportunity you have to confront the numerous challenges of Olabisi Onabanjo University. The Lord will be your light, strength and guide at all times. Amen.

I am also particularly grateful to all members of the Faculty of Science most especially the present and past Deans, Heads of Department, Coordinators of Programme and all other Staff members both academic and non teaching and most especially all members of the young Department of Microbiology where I had the privilege to serve twice as Head.

To my students, both the current and those that have graduated, I thank you all for your cooperation and good working and win-win relationship we had over the years. I must break the unwritten rule I had observed so far by mentioning names of Mr. Julius Ajayi, and Dapo for your selfless efforts and sacrifices you made on my behalf as regard this event. Your labour of love will be rewarded by our Lord. Amen.

I want to recognize the presence of my children, Oluyemi, Oluwatobiloba and Omotayo. I thank God for the peace, joy and love that accompanied you into our home. I am proud of you all.

Deep from the bottom of my heart, I thank all the distinguished guests who have come from far and near to grace this occasion.

Finally, I appreciate my only wife, Mrs. Oluwaseun Adebajo. I am sincerely appreciative of the love, care and support since we started our journey together.

Mr. Vice Chancellor, Sir, distinguished ladies and gentlemen, I thank God for this day and I thank you all for being such a wonderful audience. May God bless you all.

And to Him be all the Glory, Majesty and Honour now and forever more. Amen.

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