NATIONAL OPEN UNIVERSITY OF NIGERIA

SCHOOL OF SCIENCE AND TECHNOLOGY

COURSE CODE: HCM 431

COURSE TITLE: ADVANCED FOOD AND BEVERAGE PRODUCTION

COURSE DEVELOPMENT

HCM 431

ADVANCED FOOD AND BEVERAGE PRODUCTION

COURSE MAIN TEXT

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Introduction

Microbiology has transformed our understanding of the world. Infectious diseases are well understood, prevented or cured now. Areas of interest which concern food microbiology are food poisoning, food spoilage, food legislation and food preservation. Pathogens in food result in major public health problems. Fermentation is a relatively efficient low energy preservation process which increases the shelf life and decreases the need for refrigeration or other forms of food preservation technology.

What you will learn in this Course

During this course, the students will learn about:

- Overview of microbiology
- Microbial growth
- Food microbiology
- Food borne pathogens and sanitation
- Test kit for bacterial count
- Food spoilage
- Spoilage: meat and fish
- Spoilage: fruits and vegetables
- Food preservation
- Food additives
- Fermentation
- Microorganism used in food and beverages preparation
- Fermented foods

Working through this Course

For a successful completion of this course, one is required to go through the study units, reference books, and other resources that are related to each unit.

The Tutor-Marked Assignments (TMA) should be done immediately and submitted to the Course Facilitator.

The medium and time for the submission of the TMA will be specified later. This is a two (2) credit unit course, and so you are expected to spend a minimum of two (2) hours on it weekly. It is expected that you complete the entire course outline in 18 – 25 weeks.

Course Evaluation

As earlier stated, every unit of this course has an assignment section which you are expected to do at the end of the unit. You are required to keep an assignment file. At the end of the course, the evaluation shall be as follows:

Assessment	Marks
Assignments	30%
Examination	70%
Total	**100%**

Out of the assignments you will do, each shall be marked and converted to 3%. At the end, the best ten(10) shall be selected to make up 30%. The examination at the end of the course shall cover all aspects of the course.

Study Units

The studytopics to be discussed have been grouped in units and modules as shown below:

Module 1

Unit 1 Overview of microbiology

Unit 2 Microbial growth

Unit 3 Food microbiology

Unit 4 Food borne pathogens and sanitation

Unit 5 Test kit for bacterial count

Module 2

Unit 1 Food spoilage

Unit 2 Spoilage: meat and fish

Unit 3 Spoilage: fruits and vegetables

Unit 4 Food preservation

Unit 5 Food additives

MODULE 3

Unit 1 Fermentation

Unit 2 Microorganism used in food and beverages preparation

Unit 3 Fermented foods

The units shall be treated in sequential order.

Textbooks and References

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MODULE 1

Unit 1 Overview of microbiology
Unit 2 Microbial growth
Unit 3 Food microbiology
Unit 4 Food borne pathogens and sanitation
Unit 5 Test kit for bacterial count

UNIT 1 OVERVIEW OF MICROBIOLOGY

Content

1.0 introduction

2.0 objectives

3.0 main content

3.1 what is microbiology?

3.1.1 uses/roles of microorganisms

3.2 microscopic examination of microorganisms

3.2.1 microscopes3.2.2 staining techniques

3.2.2.1 gram staining technique

3.2.2.2 observation and result of gram staining

3.3 characteristics of microbes

3.3.1 the prokaryotes

3.3.2 the eukaryotes

3.4 morphological characteristics of microorganisms

3.5 structure of bacteria

3.6 classification of bacteria based on microscopic morphology

3.6.1 growth pattern of bacteria in liquid broth culture

3.6.2 classification of bacteria based on biochemical test

4.0 conclusion

5.0 summary

6.0 tutor-marked assignments

7.0 references/further reading

1.0 INTRODUCTION

Microbiology, the study of microscopic (very small) forms of life, has transformed our understanding of the world. Throughout most of history, people had no knowledge of the minute organisms that exist everywhere, and the implications of this ignorance were huge. Infectious disease could not be understood, prevented or cured, prior to the discovery of microorganisms. Modern infectious disease medicine is built upon a solid understanding of microbiology.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

1. Define microbiology.

2. Classify microbes into 5

3. State the roles of microorganisms

4. Practise at least 5 ways of identifying microorganisms.

3.0 MAIN CONTENT

3.1 What Is Microbiology?

Microbiology is the study of tiny or minute living organisms that are not directly visible to the unaided eye or naked eye but are only visible with the use of microscopes. Microbiology can also be defined as a specialized area of biology that deals with living things too small to be seen without magnification. These microorganisms are collectively called microorganisms or microbes.

They can be divided in 5 groups:

Plural	**Singular**
Bacteria	Bacterium
Fungi	Fungus
Viruses	Virus
Algae	Alga
Protozoa	Protozoa

Microbiology studies the diversity, evolution, beneficial and harmful role to mankind and their environmental as a whole. This is because microorganisms affect all forms of life on earth.

3.1.1 Uses/roles of microorganisms

Microbiology helps man to understand the basic life processes on earth and also helps him to make use of this knowledge to his benefit. The following are some of the roles ofMicroorganisms which may be beneficialand harmless or harmful and pathogenic to man, plant or animal and their environment.

1. **Microorganism and Agriculture**: Microorganisms can cause diseases in plants and animals thereby bring about economic loses to the farmers and the nation as a whole. Ruminant animals also benefit from the activities of the microbes that are living in their domain. These organisms help the animals to digest cellulose rich diets. The

association between leguminous plant root nodules serves to convert atmospheric nitrogen to ammonia which the plant can readily use for their growth, thus reducing the need for expensive and polluting nitrogen fertilizer.

2. **Microorganisms and food**: Food is an essential medium or material rich in nutrient that can support life including that of microbes. This makes it easy or possible for organisms to cause food poisoning when they contaminate such food. When this happens, the food decays, gives off flavours and it is unsuitable for consumption. Food spoilage causes economic loses to man.
   Fermentation is another important activity in which microbes are useful.
   They are used in the fermentation of alcoholic beverages e.g. beer, cheese, yoghurt and in baking where yeast is used to raise dough. Microbes can also make use of food as material for transmitting food borne diseases. The food material is referred to as 'vehicle of infection'.
   Water can serve as a vehicle for the transfer of cholera; salad can serve as a vehicle of transfer for food poisoning.

3. Microbes are useful in the recycling of some nutrients in nature e.g. the carbon, nitrogen and oxygen cycles that take place in nature. The activities of some microbes also produce natural gases such as methane. Some other microbes are used on agricultural waste, domestic waste and some industrial waste to generate bio fuel such as ethanol and methane. For example ethanol is produced by microbial fermentation of glucose from sugar cane or corn starch and is the major motor fuel in some countries such as Brazil. Microorganisms are also natural cleaning up agents in their environment, they have bioremediation abilities for example some microbes have the ability to clean up spilled oil, pesticides or toxic environmental pollutant by degrading such materials.

4. **Microbes and medicine**: A large number of microbes cause diseases in animals, plant and man. These organisms may use vector (i.e. living organisms e.g. fly, mosquitoes, and cockroaches) or vehicle (i.e. inanimate objects) to transmit diseases from one person to another. The knowledge of the harmful roles of microbes has helped in the identification of new diseases, development, treatment and prevention of such diseases.For example, the use of antibiotics and improved sanitary and public health practices. The microbes that cause diseases are called pathogens.

5. **Microorganisms and biotechnology**: some microbes are used in the manufacturing of some products of commercial values e.g. vaccines, antibiotics, hormones. They are also useful in the food industry in the production of fermented products on a large scale.
   Biotechnology is the use of genetically modified microbes to synthesis products e.g. human insulin is produced by modified bacteria

3.2 Microscopic examination of microorganisms

This is usually the first step in the identification of an organism. Due to the very small size of these organisms there is the need to magnify them in order to view and study their internal organelles.

3.2.1 Microscopes

These are instruments that are used to magnify objects. There are two types,

1. Electron microscope and
2. Light microscope

Light microscope: Its name is derived from the fact that it uses the light source for its illumination. The light may be natural sunlight or electricity. The different types of light microscopes include:

1. Bright field
2. Dark field
3. Phase contrast
4. Fluorescence
5. Confocal scanning laser microscope

The electron microscope

This uses the electron beams and it is usually used to view virus and large molecules. The major difference between it and the light microscope is their source of illumination. Examples of electron microscopes are

1. Transmission electron microscope and
2. Scanning electron microscope

3.2.2 Staining techniques

This involves the application of different stains and dyes on prepared specimens to enhance their visibilities under the microscope. Staining is majorly done because the cytoplasm of most organisms iscolourless making it difficult to observe theorganism. Therefore staining is done to enhance visibility to emphasize specific morphological features (structural features) and also to preserve stained specimens for future use.

Different staining techniques include

1. Gram staining technique
2. Spore staining technique
3. Capsule staining
4. Flagella staining
5. Acid fast staining

Before staining, the specimen must be subjected to some treatment such as

1. Smear preparation: this involves spreading a thin film of the cell suspension on a glass slide and allowing it to dry.
2. Fixation: this involves passing the air- dried smear through a flame and allowing it to gently heat up. The heating kills and fixes the cell on the slide; it also inactivates enzymes that may change the morphology of the cell. It also toughens the cell so that it does not change during staining and observation. Apart from the use of heat, chemicals can be used in fixation e.g. ethanol, acetic acid etc.
3. Staining: this is done by the application of dyes to the specimen to impart colours through achemical reaction that allow the dyes to buy into the cell.

There are two major groups of stains used, they are basic dyes and acid dyes.

Basic dyes	**Acid dyes**
Crystal violet	Eosin dye
Methylene blue	Congo red
Basic fuchsin	Indian ink
Saframin	Black stain
Malachite green	rose Bengal

The basic dyes are positively charged and are attracted to the negative charge of the cytoplasm, while the acid dyes are negatively charged and are repelled by the negative charge of the cytoplasm, thus the stain gathers around the edge of the cell.

Staining methods can also be simple ordifferential.

3.2.2.1 Gram staining technique: it is an example of simple staining. It was developed in 1884 by Christian gram. It is an important staining technology in microbiology which is used to differentiate bacteria into gram positive and gram negative based on the cell wall of the organism.

Procedure for gram + and gram – bacteria)

1. Make a smear of the specimen on a clean glass slide and allow it to dry.
2. Heat fix the smear by passing through frame 2-3 times
3. Flood the slide with crystal violet on the slid and allow it to dry
4. Wash off excess dye with water
5. Add grams iodine and wait for 60 seconds
6. Flood the slide with alcohol or acetol and leave it for 10 seconds.
7. Wash off excess with water
8. Counter stain with cabon fuchsin or safrain
9. Wash off excess with water
10. Blot dry the slide and observe under the microscope

3.2.2.2 Observation and result of gram staining

1. If a purple or violetcolour is seen the bacterium is a gram positive bacterium. This is due to the ability of the cell to retain the primary dye and resist decolourisation
2. If a pink or red colouration is observed the organism is a gram negative bacterium. This is because alcohol is able to decolourize the primary stain making it possible for the cell to obtain and retain the counter stain.

Roles of the different stains or reagents used for gram staining

1. Crystal violet: this is the first primarystain and it colourizes the specimen purple or violet.
2. Grams iodine: this is the mordant, it enhances the interaction between the cell and the dye so that the cell can take up the colour more strongly
3. Alcohol or acetol: this is the decolourizer and it determines if the cell is going to be decolourized or not of the primary stain
4. Safranin / carbol fuchsin: this is the counter stain that gives the pink or reddish colour to the cell after it had been decolourized.

Crystal violet	Gram's iodine	Alcohol or Acetol	Safranin or carbol fuchsin
1. Gram + bacterium Purple	purple	purple	purple/violet
2. Gram – bacterium Purple	purple	Cell is decolourised	Red/pink

3.3 Characteristics of microbes

Microbes are not all alike, they vary in size,shape,structure and function, but they share a common feature which is, that they are microscopic. They are usually unicellular in nature and most are classified under the kingdom Protista. All living things may be divided into two groups:

a. The prokaryotes and
b. The eukaryotes

3.3.1 The prokaryotes

They are simple organisms composed of single cells having no membrane bound intracellular organelles. They lack a well-developed nucleus and their ribosomes are free in the cytoplasm. Examples include: bacteria and blue-green algae

3.3.2 The eukaryotes

They possess nucleus with a well-defined nuclear membrane. They also have membrane bound organelles such as mitochondria in the cytoplasm. Examples are protozoa and fungi.

	Prokaryotes	**Eukaryotes**
Nucleus	Not well defined	True nucleus
Nuclear membrane	Absent	Present
Chlorophyll	When present it is dissolved in cytoplasm	When present it is found in the chloroplast
Cell wall	It is usually made of peptidoglycan	It contains cellulose or chitin
Reproduction	Asexual method	Both sexual and asexual
Organelles	Few external organelles	Many internal organelles
Chromosome	One	Many
Ribosome	Small	Large
Mitosis	No evidence	Takes place

3.4 Morphological characteristics of microorganisms

1. **Protozoa**: They are unicellular animals that live in aqueous environments such as ponds, majority are free living and harmless e.g. amoeba. While a few are parasitic and cause diseases for example Entamoeba histolytica, plasmodium sp

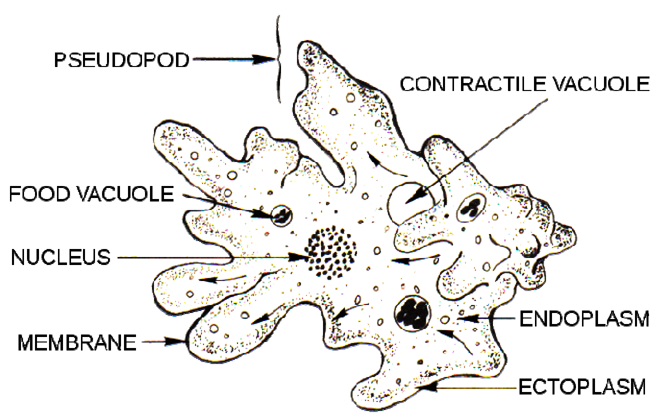


Fig 1: Structure of Amoeba

2. **Algae**: All algae manufacture their food through photosynthesis. They may be micro or macroscopic in size e.g. sea weeds. They are usually free living and harmless e.g. in the green slime or surface of pond and algae. Algae are pigment organisms, they are eukaryotic but lack well developed vascular system. They have chlorophyll and

reproduce asexually and sexually. They also store their carbohydrate as glucose e.g. Euglena

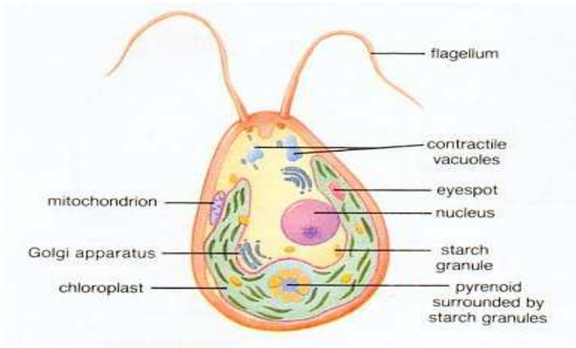


Fig 2: Algae Structure

3. **Viruses**: They are the smallest of all the microbes e.g. bacteriophage. They are obligate intracellular parasites that depend on their host for all their metabolic activities thus outside their living host they are metabolically inactive and are often referred to as crystalizable chemicals. When inside the host they redirect the activities of the host cells to replicate themselves. Viruses do not grow on artificial media. They contain either DNA or RNA but never both. The DNA and RNA are enclosed in a layer of protein called capsid. Viruses are cellular organisms i.e. they lack cellular organization. They cause diseases in both plants and animals. Viruses also infect bacteria and such bacteria are called bacteriophage.

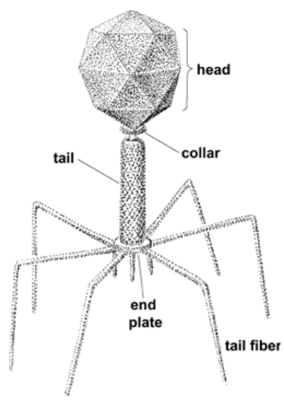


Fig 3: A Simple Diagram Of A Bacteriophage

4. **Fungi**: They are eukaryotic organisms that lack chlorophyll and flagella. They may exist as multicellular filamentous hyphae or unicellular. The unicellular fungi are referred to as yeast. They are unicellular because they exist as single cell organisms, although a large mass of yeast can be seen by the naked eye, they are individually microscopic. They are found on leaves, flowers and secretion of leaves, they can also be found on the skin and alimentary canal of man. Some yeast is pathogenic to man, animal or plant. They are also useful in several industries to produce wine, beer and bread because they are able to ferment sugars to produce Co_2 and alcohol. Example of yeast include saccharomyces cerevisae, candida albicans

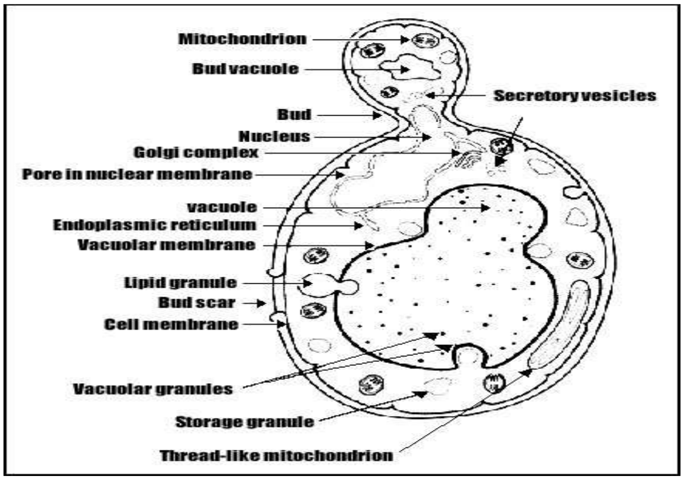


Fig 4: Yeast structure

Molds: The multi-cellular filament cells are called molds. They can be found on a damp newspaper, old leather, decaying wood, rotten food or walls. Etc.

They are called multicellular cells because they are composed of many cells joined together. They are able to break down organic materials into simple forms. They are often involved in food spoilage. E.g. rhizopus sp causes spoilage in bread. They also cause diseases e.g. ringworm. Moulds are also useful when they grow on some food e.g. the ripening of cheese. Moulds are made up of many threads called hyphae. A collection of these hyphae are called mycelium. Reproduction may be asexual or sexual. Examples include penicillium sp and aspergillus sp

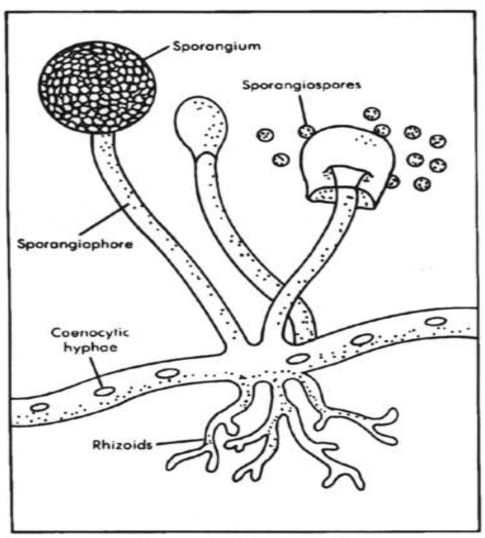


Fig 5: Rhizopus

5. **Bacteria**: They are prokaryotic organisms which reproduce by binary fission, they are unicellular organisms with various nutritional requirements and some may live in an oxygen-- rich environment or oxygendeficient environment. Bacteria that live in an oxygen- rich environment are called aerobic bacteria and those that live in an oxygen-deficient environment are called anaerobic bacteria. Growth may also be at different

temperature depending on the type of bacteria and where it is found. They may be found in the soil, plant, water or man. The shape and arrangement of bacteria also differ. Bacteria may be gram positive or negative depending on their reaction to gram staining. They may also possess additional structure such as flagella capsule and endospores. The cell wall of bacteria is peptidoglycan and it gives shape to the bacteria. It can be pathogenic to man, plant and animal.

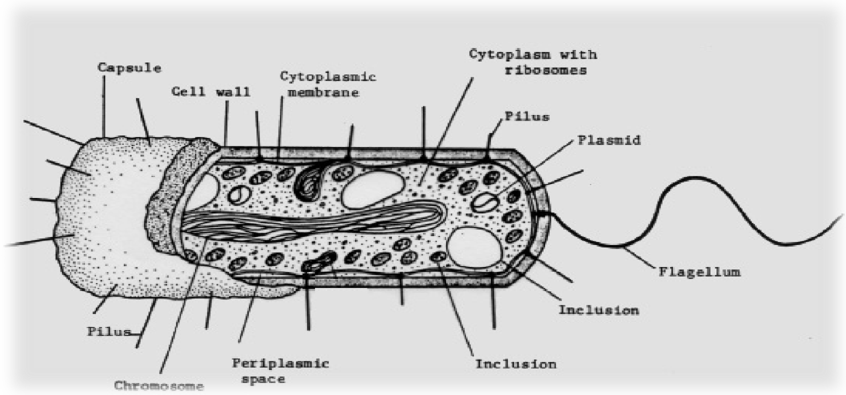


Fig 6: A simple structure of bacteria

6. **Mycoplasma**: These are bacteria that lack cell wall because they cannot produce peptidoglycan. They are pleomorphic i.e. they have no rigid shape, their sizes vary and their genetic material is the smallest among prokaryotes. Example Mycoplasma sp

7. **Rickettsiae**: They are intracellular parasites believed to be between bacteria and viruses due to their small size and intracellular nature. They may be rod shape or coccibut some may be pleomorphic (no shape) e.g. rickettisae typhi, rickettsiae prowazeki.

8. **Cyanobacteria (or the blue-green algae)**: They appear green due to the pigment they contain. They are photosynthetic bacteria. They may exist as unicellular or filamentous form. Their cell wall is similar to that of gram negative bacteria. They are believed to be between bacteria and algae because their photosynthetic system closely resembles that of algae.Example of cyanobacteria include nostoc, anabaena sp and Oscillatoria

3.5 Structure of bacteria

All bacteria have the same internal structures regardless of their individual shape.
This may include the following:

1. The rigid cell wall
2. Cell membrane
3. Double stranded DNA
4. Ribosomes
5. Cytoplasm

6. Mesosome
7. Storage granules and additional structures such as;
    a. Flagellum
    b. Capsule
    c. Endospores

The outer layer of the bacterial cell is called a cell wall. It is rigid strong and it maintains the shape of the organism. It also acts as a barrier to certain compounds. The cell wall is made of peptidoglycan layer which is thicker in gram positive than gram negative bacteria. The cell membrane controls the entry and exits of all substances and it surrounds structures within the cell cytoplasm. The DNA is the nuclear material that carries the genes of the cell which determines the nature of the bacterium. The cytoplasm is made of water, sugar, amino acids, salt etc. and it supports the ribosomes, glycogen and lipids.

Themesosome is found in many gram positive bacteria and it is important in cell division.

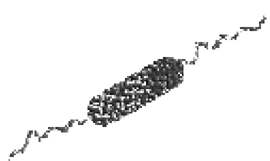
Additional structures

1. **Flagella**: A flagellum is a thread-like appendage attached to the cell membrane. It is a locomotion appendage responsible for the mobility of the bacterium. The pattern of distribution of flagella in bacteria differs. There are four (4) different distribution patterns:

a. Monotrichous distribution

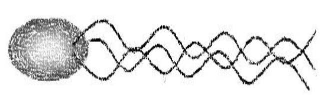
This is observed in bacteria that have single flagellum located at one end of the bacteria. Example, Vibro cholera

b. Amphitrichous distribution



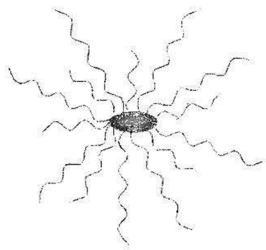
This is when oneflagellum is seen attached to each end of the bacteria. E.g. Pseudomas aeruginosa

c. Lophotrichous distribution



This is bacteria that has a cluster of tuft of flagella at one end or at both ends. E.g. Alaligens Faecalis

d. Peritrichous distribution



This occurs when flagella are evenly spread over the whole outer surface of the bacterium. E.g. proteus mirabilis

2. **Capsule**: This is a layer of gelatinous material produced by the bacterial cell itself which adhere to the outside of the bacterial cell. The function is to protect the bacterium against destruction. Bacteria that have capsule are said to be encapsulated. Examples are Bacillus subtilis and bacillus anthracis

3. **Endospores**: these structures are commonly referred to as spores. They are spherical or oval structures formed within a vegetative bacterial cell. They contain enough materials to sustain them when they are released from the parent cell. A mature spore can remain in a dormant state for a very long period because they have extra ordinary resistance to heat, cold and chemicals. They can survive in dust, vegetation or in the soil for several months or years until it finds a suitable environment for reproduction. The position of spores in cells includes the following:
   a. Central spore: this occurs when the spore is located at the centre of the bacterium. Example Bacillus anthracic
   b. Sub terminal spore: this is seen when the spore is located towards one end of the bacteria. Sometimes the diameter will be greater than that of the cell thereby causing the cell wall to bulge forming a single spindle. Example Clostridium Botulium
   c. Terminal Spore: this is when the spore is located at one end of the bacterial cell. If the diameter of the cell is greater than that of the bacteria, it bulges and gives a drum stick appearance. Examples are Bacillus Subtilis, Clostridium tetani

3.6 Classification of bacteria based on microscopic morphology

1. Bacterial shape: when bacterial specimen are strained and viewed under the microscope, different shapes and arrangements can be observed. This can be used for preliminary identification
   a. Coccus: These are spherical or near spherical cells. There are varieties of arrangement for cocci cells
      i. Cluster arrangement: When you have cluster arrangement they are said to be staphylococci. Example staphylococcus Aureus
      ii. Chain arrangement: this is when the cocci cells are arranged in chains. They are said to be streptococci. Example streptococcus pyogenes

iii. Pair arrangement: When this occurs they are said to be diplococcic. Example streptococcus pneumonia

b. Bacillus: This is a rod shaped cell. It may have rounded ends or large square ends
c. Vibrio: These are comma shaped rod cells
d. Spirillium: these are spirally shaped curved rods.

Apart from shape other microscopic morphological classifications that are used include:

1. Colony shape
2. Colony margin or edge- smooth, serrated
3. Colony elevation- flat, raised on the agar
4. Colony surface- wrinkle, smooth, glittering, dull
5. Colony pigmentation- colour
6. Odour- sweet, decay, fruity.

3.6.1 Growth pattern of bacteria in liquid broth culture

1. Turbidity: This occurs when the bacteria are suspended in the broth culture
2. Flocculence: This occurs when the bacteria floats in clumps
3. Ring Formation: This occurs when there is formation of ring around the top rim of the medium
4. Pellicle Formation: This is seen when the bacteria float in a heavy pellicle of the surface of the medium
5. Sedimentation: This is when particles settle at the bottom of the culture vessel.

3.6.2 Classification of bacteria based on biochemical test

The various biochemical tests used to confirm the identification of bacteria include:

1. Carbohydrate fermentation teat
2. Coagulase test
3. Indore test
4. Catalase test
5. Citrate test
6. Oxidase test
7. Nitrate reduction test
8. Urease test

SELF-ASSESSMENT EXERCISES

Differentiate between prokaryotes and eukaryotes

4.0 CONCLUSION

A good knowledge of the structures, functions, characteristics and how to identify microorganisms will help a great deal in serving healthier and safer meals to our patrons.

5.0 SUMMARY

Microbiology can be defined as a specialized area of biology that deals with living things too small to be seen without magnification. These microorganisms are collectively called microorganisms or microbes. Microbiology helps man to understand the basic life processes on earth and also helps him to make use of this knowledge to his benefit. Due to the very small size of these organisms there is the need to magnify them in order to view and study their internal organelles. Microorganisms can be identified in several ways e.g.microscopic examination, staining techniques.

All living things may be divided into two groups:

a. The prokaryotes and
b. The eukaryotes
   All bacteria have the same internal structures regardless of their individual shape.
   This may include the following:
   8. The rigid cell wall
   9. Cell membrane
   10. Double stranded DNA
   11. Ribosomes
   12. Cytoplasm
   13. Mesosome
   14. Storage granules and additional structures such as;
       d. Flagellum
       e. Capsule
c. Endospores

6.0 TUTOR-MARKED ASSIGNMENTS

Go to the microbiology laboratory and with the assistance of the lab.Scientist,practise the classification of bacteria based on:
a.Microscopic morphology (e.g shape,colony colour,odour etc)
b.Biochemical tests
2. Report and submit your findings.

7.0 REFERENCES

1. Bauman, R. (2007) *Microbiology with Diseases & Taxonomy*, Pearson Benjamin Cummings.

2. Tortora, G., Funcke, B., Case, C. (2010) *Microbiology, an Introduction.* Benjamin Cummings.

UNIT 2 MICROBIAL GROWTH

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1.0 INTRODUCTION

Growth in microbes refers to cell growth and increase in cell population. For growth to occur there is need to provide suitable materials that the cell will need together with sources of energy and water. The type of nutrient provided is determined by the normal habitat of the organism.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

1. Identify 2 groups of media

2. Differentiate 4 different types of media

3. Describe the requirements for growth of microbes

4. Analyse the 4 phases of microbial growth

5. Discuss at least 5 factors influencing microbial growth

3.0 MAIN CONTENT

3.1 Cultivation of microorganism

Culture media can be grouped based on the component of the media.

There are two groups of media:

i. Defined or synthetic medium (known)
ii. Complex medium (unknown ingredient)

3.1.1 Defined medium/synthetic medium

This is a medium in which all the components are known. It is usually a relatively simple medium having a carbon source, nitrogen, sulphur, phosphorous and a variety of mineral sources. These elements are usually obtained from carbon dioxide (Co_2). Defined media are widely used in research.

3.1.2 Complex Medium

This contains some ingredients of unknown chemical composition such as yeast extract, peptone, meat extract etc. from which carbon, nitrogen, sulphur and phosphorus are obtained. Complex media are mostly used in everyday cultivation, adding ingredients of unknown composition.

3.2 Types of Media

There are four different types of media

1. General purpose media
2. Enriched media
3. Selective media
4. Differential media

3.2.1 General media: They support the growth of a wide range of microorganisms. Example include nutrient agar (solid), Nutrient broth (liquid), Tryptic soy agar (solid), Trypic Soy broth (liquid), potatoes dextrose agar (used for fungi)

3.2.2 Enriched media: These are media prepared by fortifying a general purpose media with blood or other special nutrient. Example Blood agar

3.2.3 Selective Media: These are media that favour the growth of specific microorganism while inhibiting the growth of others. Example mac conkey agar (used to differentiate between lactose fermentation and non-lactose fermentation), endo agar, eosine methylene blue agar

3.2.4 Differential media: These are used to differentiate between grouped bacteria. They can also be used to tentatively identify microorganism. Example blood agar which is used to distinguish between haemolytic and non haemolytic bacteria

3.3 Requirement for growth

All microbes require these nutrients, carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, magnesium, iron and some other element in trace amounts. These may be obtained from inorganic or organic sources. Organisms also need energy in order to utilize the nutrient that has been taken up. These energies can be derived from sugar or sunlight. The sugars are obtained from different food sources while sunlight is utilized by photosynthetic organism.

Another essential component is water. It is a medium in which the majority of the chemical reactions within the cell take place. It is also useful in the movement of soluble substances into the cell and the passage of waste materials out of the cell. The amount of liquid water available in food is known as water activity. Different organisms have different requirements for water. Example, bacteria grow better in high water activity, yeast survives in less and molds in the least water activity.

When foods are dried to preserve them, most microbes may be deprived of water. However if during damp storage conditions the water rises, the food will increasingly support the growth of mold, followed by yeast and finally by bacteria

3.3.1 Microbial growth curve

Bacteria divide by binary fission resulting in one parent cell yielding two daughter cells. The time required by bacteria to double under optimum conditions is known as ‘generation time’ this is however dependent on environmental conditions in which the microbes live. The population of bacteria cells in a culture vessel may undergo several changes described as phases of growth. There are four phases of growth:

- The lag phase
- Exponential or logarithmic phase
- Stationary phase
- Death or decline phase

3.3.1.1 The lag Phase

Immediately after inoculating the bacterial cells into a medium, it undergoes a period of adaptation where it becomes adapted to its environment. During this phase necessary enzymes and metabolites are produced. Also the bacteria population increases in size and metabolic activities. There is no reproduction in this phase and the duration of the phase is dependent on the size of the inoculum culture medium used and environmental factors.

3.3.1.2 Exponential or log phase

When the cells are adapted with the media, they multiply with time until the maximum number that can be supported by the environment is reached. On the growth curve this is represented by a straight line. During log phase reproduction is at the highest and death at the lowest.

3.3.1.3 Stationary phase

Growth slows down at this phase because of depletion of nutrients, accumulation of waste products, overcrowding and other factors such as production of toxins or antibiotics. At this phase the number of cells that die equals the number of cells produced, thus resulting in no overall increase in the number of cells living. This is represented by the horizontal line in the curve.

3.3.1.4 Death or decline phase

The nutrient depletion and accumulation of toxic waste leads to decrease in viable living cells. Thus reproduction is at the lowest and death at the highest. If the cells are not transferred to another favourable environment they will all die. Sometimes a small number of surviving cells may persist for months after death of the majority because they grow on the nutrients released by the dead cells.

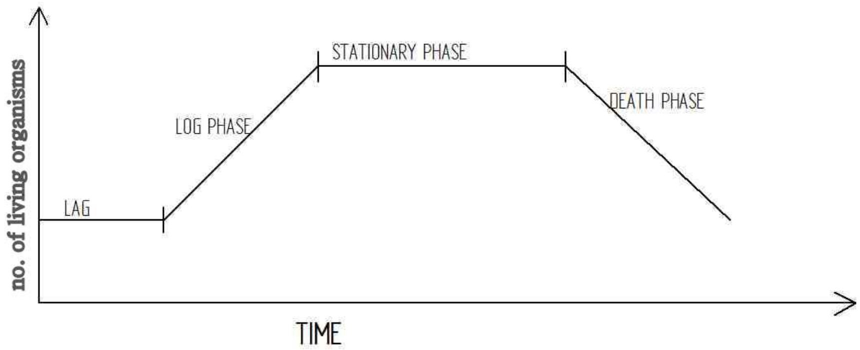

Fig 1: microbial growth curve

3.4 Factors influencing microbial growth

Different species of microbes require different physical and chemical factors for optimum growth. These include the following:

1. Temperature: there are three temperature ranges that will permit increase in the growth of an organism. Beyond this, growth will be greatly affected. These temperature ranges are:
   i. The minimum temperature range
   ii. The optimum = +10 – 15^{o}c
   iii. The maximum temperature range

   Below the minimum temperature range, multiplication of the organism will not occur. Above the minimum temperature range growth is stimulated causing more rapid self-divisions. This is the optimum temperature at which the growth of the organism is highest. As the temperature increases above the optimum, growth is affected until the maximum temperature is achieved, and if it gets above the maximum temperature the growth will stop.

   Microorganism can be classified based on their temperature requirement

   a. Psychrophiles: these are found in cold temperature e.g. refrigerators and freezers where they may grow and spoil stored food. E.g. penicillium, Bacillus species. The optimum temperature = +10 – 15^{o}c
   b. Mesophiles: They are found in the warm bodies of warm blooded animals. Some are pathogenic to man and animal with optimum temperature of 37^{o}c which corresponds to that of human temperature. They may also be found in the soil or water. E.g. streptococcupyogenes, staphylococcus aureus.
   c. Thermophiles: They prefer higher temperature than mesophiles with optimum temperature of (45- 55^{o}c)

2. PH: This is a scientific term describing in numbers the acidity or alkalinity of a fluid. Microorganisms can only grow and multiply within a certain PH range.
   a. Neutrophiles: They prefer to live in a neutral environment near PH 7. Most organisms are neutrophils
   b. Acidophiles: These organisms prefer acidic medium and will not grow well on a neutral environment. Prickling of food prevent the food from spoilage by neutrophils but not acidophiles.
   c. Alkalinophiles: These organisms prefer alkaline environment.

3. Oxygen: all organisms respire, using oxygen to generate energy. However the requirement for oxygen differs for organisms.
   a. Aerobic organisms: they need oxygen for their metabolic processes.
   b. Anaerobic organism: They do not require oxygen and may not thrive in the presence of oxygen
   c. Facultative anaerobic organisms: These are able to adapt in the presence or absence of oxygen
   d. Microaerophilic organisms: they require minute oxygen for growth.

4. Water activity (a_w): Most organisms grow between a_w of 0.99 to 0.90 containing dissolved nutrient and gases. Dried foods kept dry will keep for long period because

they do not allow the growth of organism. The resulting dried products can contain many living cells that can grow if the right a_w is reached.

5. Pressure
6. Salinity

3.5 Isolation of pure cultures

Microorganisms co-exist with countless other microbial species. This natural state which different species co-exist is called a mixed culture. A pure culture is a population cell arising from a single cell to a characterized individual species. It is necessary to obtain pure culture for future studying of the organisms and its activities. Aseptic techniques are useful in achieving this. Aseptic techniques are those techniques in which materials are handled in such a way that unwanted microbes are not introduced into it during isolation or handling. It involves the:

i. Sterilization of media and glass wares. This is achieved in the lab by the use of auto clave at 121^oc for 15 minutes.
ii. By transfer method; Which could be;
   a. Streak plate method
   b. Spread plate method
   c. Pour plate method
iii. Maintenance of pure culture: This can be done with the use of test tubes or mac conkey bottles containing solidified agar at a slanted angle. The pure culture can then be stored in the refrigerator, freezer, or liquid nitrogen and it can be freeze-dried. This is also called lyophilization. The culture may also be stored in glycerol at low temperatures.

3.6 Control of microorganisms

The presence of microorganisms may be beneficial or detrimental to man, animal or plant. Thus it is necessary to control their growth. Reasons for controlling microorganisms:

1. To prevent infection of man animals and plants
2. To prevent food spoilage and spoilage of other commodities.
3. To prevent interference of contaminating microbes industrial processes.
4. To prevent the contamination of specimen, media and other materials brought to the lab.

Control methods include the following:

1. Application of heat: temperature affects the rate at which microbes are grown and when heat is applied above maximum temperature for growth, some of the cell structure and membrane are damaged, thus killing the cell.
2. Sterilization: Is the process by which all living cells, spores or viruses are destroyed or removed from an object or habitat. It ensures that no life is in or on the material. Sterilization can be achieved by the use of the moist/wet heat through the use of autoclave. For example in food industries spores of organisms such as clostridium

botilinum are destroyed by subjecting the food product to moist heat. Heat treatment can also be achieved by applying dried heat and this is usually used in the lab to sterilize glassware and other materials used in the lab. This is also achieved by the use of hot air oven. Other dry heat method include:

i. Flaming and incineration
ii. Use of chemicals substance: substances that have advance effect on microbes which also prevent cell growth or lead to cell death are called antimicrobial agents.

Antimicrobial agents include:

1. Disinfectants
2. Antiseptic
3. Sanitizers
4. Antibiotics

   They are often used in hospitals, food factories and in homes

1. **Disinfection**: is the killing or inhibition of microbes that may cause diseases or infections. They are usually used in inanimate objects because they are harmful to the human tissue. They do not fully kill the microbes because some spores of cells may remain after treatment with disinfectants. E.g. Chlorine

2. **Antiseptic** It is the prevention of infections by destroying living microorganisms on living tissues. The chemical used are antiseptics. They also do not remove all the microbes but they can reduce their level that which is not harmful to man. E.g. potassium iodide. An antimicrobial agent maybe cidal or static. Cidal indicates killing while static indicates prevention or inhibition.

3. **Sanitization**: it is the process whereby microbial population of inanimate objects are reduced to levels judged to be safe by public health standard, they are usually used in food restaurants and food factories e.g. hypo chloride.

4. **Irradiation**: This can be achieved through the use of radiation such as gamma rays or x-rays. They affect the DNA of bacteria leading to death. Other radiations used include: infra-red rays, ultraviolet rays, which also have the ability to denature bacterial protein, damage the DNA and prevent DNA replication. Ultraviolet rays can be obtained from sunlight.

3.6.1 Conditions influencing the effectiveness of antimicrobial agents

1. Population size: the larger the population, the longer time required for the antimicrobial agent to be effective.
2. Population composition: If the bacteria population contains young cells, spores, resistant cell, it will take a longer time for the antimicrobial agent to work.
3. Concentration or intensity of microbial agent; Use of incorrect concentration may cause the multiplication of resistant cells which may be difficult to eradicate.

4. Duration of exposure: The longer the contact time, the greater the effect
5. Temperature: Higher temperature enhances effectiveness
6. Local environment/surrounding: presence of flood, hardness of water or dirt may affect the effectiveness.
7. PH; The PH of the agent will affect the effectiveness of the microbial agent.

3.6.2 Products of microbial growth

The growth activities of noys yield waste products which may be retained inside the cell and released on cell death or may be secreted into the medium as the organism grows.

1. Gases i.e. $Co_{2,}$ H_2s
2. Acids i.e. Lactic, propionic, acetic
3. Alcohol
4. Aromatic compound which gives flavours or off-flavours, taints
5. Antibiotics
6. Toxins

SELF ASSESSMENT EXERCISES

Visit a microbiology shop and observe the different types of media available.

a. CONCLUSION

The presence of microorganisms may be beneficial or detrimental to man, animal or plant. Thus it is necessary to control their growth.

5.0 SUMMARY

Growth in microbes refers to cell growth and increase in cell population. For growth to occur there is need to provide suitable materials that the cell will need together with sources of energy and water. Growth in microbes refers to cell growth and increase in cell population. For growth to occur there is need to provide suitable materials that the cell will need together with sources of energy and water.

All microbes require these nutrients, carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, magnesium, iron and some other element in trace amounts. When foods are dried to preserve them, most microbes may be deprived of water. However if during damp storage conditions the water rises, the food will increasingly support the growth of mold, followed by yeast and finally by bacteria. Microorganism can be classified based on their temperature requirement.

a. TUTOR-MARKED ASSIGNMENTS

See the lab. Scientist in your lab and practice the 4 phases of microbial growth

7.0 REFERENCES

1. Bauman, R. (2007) *Microbiology with Diseases & Taxonomy*, Pearson Benjamin Cummings.

2. Tortora, G., Funcke, B., Case, C. (2010) *Microbiology, an Introduction.* Benjamin Cummings.

UNIT 3 FOOD MICROBIOLOGY

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1.0 introduction

2.0 objectives

3.0 main content

3.1 parameters affecting the growth of microorganisms

3.2 food contamination

3.2.1 sources of contamination

3.2.2 primary sources of microorganisms in food

3.2.3 preventing food contamination

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1.0 INTRODUCTION

Food microbiology is the study of the microorganisms that inhabit, create, or contaminate food.
Food microbiology encompasses the study of microorganisms which have both beneficial and deleterious effects on the quality and safety of food.
Food microbiology focuses on the general biology of the microorganisms that are found in foods including: their growth characteristics, identification, and pathogenesis. Specifically, areas of interest which concern food microbiology are: food poisoning, food spoilage, food preservation, and food legislation. Pathogens in product, or harmful microorganisms, result in major public health problems worldwide and are the leading causes of illnesses and death.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

1. Define food microbiology
2. State the extrinsic and intrinsic parameters that affect bacterial growth.
3. Identify the sources of food contamination
4. Explain how to prevent food contamination

3.0 MAIN CONTENT.

3.1 Parameters affecting the growth of microorganisms

There are basically two parameters that affect the growth of microorganisms in food products, extrinsic and intrinsic. Extrinsic parameters are those properties of the environment

(processing and storage) that exist outside of the food product which affect both the foods and their microorganisms. On the other hand, intrinsic parameters, are properties that exist as part of the food product itself, for example, tissues are an inherent part of the animal that may, under a set of conditions, promote microbiological growth.
Following is a list of these parameters that may either result in multiplication or inhibition of microbial growth in food products.

Examples of intrinsic parameters are:

pH: It has been well established that most microorganisms grow best at pH values around 7.0 (6.6 – 7.5), whereas few grow below a pH of 4.0. Bacteria tend to be more fastidious (complex nutritional or cultural requirements for growth) in their relationships to pH than molds and yeasts, with the pathogenic bacteria being the most fastidious. Most of the meats have a final pH of about 5.6 and above; this makes these products susceptible to bacteria as well as to mold and yeast spoilage.

Moisture content (water activity [aw]): One of the oldest methods of preserving foods is drying or desiccation. The preservation of foods by drying is a direct consequence of removal or binding of moisture, without which microorganisms do not grow. It is now generally accepted that the water requirements of microorganisms should be described in terms of water activity (a_w) in the environment. Basically, the water molecules are loosely oriented in pure liquid water and can easily rearrange. When a solute is added (like salt) to water, the water molecules orient themselves on the surface of the solute, in this case the Na^+ and Cl^- ions, and the properties of the solution change dramatically. Therefore, the microbial cell must compete with solute molecules for free water molecules. The water activity of pure water is 1.00; the addition of solute decreases a_w to less than 1.00. Most foodborne pathogenic bacteria require a_w greater than 0.9, however, *Staphylococcus aureus*may grow in a_w as low as 0.86.

Oxidation-reduction potential: Microorganisms display varying degrees of sensitivity to the oxidation-reduction potential (O/R or EH) of their growth medium or environment. Aerobic microorganisms require more oxidized environments (more oxygen) versus anaerobic organisms which require more reduced environments (lacking oxygen).

Nutrient content: In order to grow and function normally, the microorganisms of concern in the food industry require the following: water, source of energy, source of nitrogen, vitamins and related growth factors, and minerals.

Antimicrobial constituents: The stability of some foods against attack by microorganisms is due to the presence of certain naturally occurring substances that have been shown to have antimicrobial activity. Nisin and other bacteriocins are good examples.

Biological structures: The natural covering of some food sources provides excellent protection against the entry and subsequent damage by spoilage organisms. Examples of such protective structure are the hide, skin and feathers of animals.

Examples of extrinsic parameters are:

Storage temperature: Microorganisms, individually and as group, grow over a wide range of temperatures. It is important to know the temperature growth ranges for organisms of importance in foods as an aid in selecting the proper temperature for product storage

Relative humidity: The relative humidity of the storage environment is important both from the standpoint of water activity (a_w) within foods and the growth of microorganisms at the surfaces. Humidity can also be an important factor to consider when producing some types of product.

Presence/concentration of gases: Carbon dioxide (CO_2) is the single most important atmospheric gas that is used to control microorganisms in foods. It has been shown to be effective against a variety of microorganisms. Because of its effectiveness, CO_2 is used as one of the methods for modified-atmosphere packaging (refer to FDA Food Code).

Presence/activities of other microorganisms: The inhibitory effect of some members of the food microbiota on other microorganisms is well established. Some foodborne organisms produce substances that are either inhibitory or lethal to others. These include antibiotics, bacteriocins, hydrogen peroxide, and organic acids (such as lactic acid). General microbial interference is a phenomenon that refers to general nonspecific inhibition or destruction of one microorganism by other members of the same habitat or environment; the mechanism for this interference is not very clear. Some of the possibilities are: competition for nutrients; competition for attachment/adhesion sites; unfavorable alteration of the environment and/or combinations of these.

3.2 Food contamination

Contamination is the occurrence of any objectionable matter in food. Food is said to be contaminated when foreign bodies, materials or harmful substances are introduced into it, which makes it dirty or impure.

These objectionable matter are called contaminants and may be organic or inorganic in nature e.g. microorganisms, chemicals, adulterants, which are not part of the food.

Food can become contaminated in a multitude of ways and contaminants enter food accidentally or incidentally from the source or farm and end on the table when food is consumed.

3.2.1 Sources of contamination

1. Agricultural Contamination: many crops are treated with insecticides, fungicides to prevent growth of fungi, and weed killers or growth regulators to kill weeds selectively. Pesticides and fungicides are invaluable aids to different food production, not only when the crops are growing but also after harvesting and when they are being stored. Many of them are toxic to animals and human beings but they are usually applied to plants before the part which is eaten has appeared or at least a sufficient length of time before harvesting to ensure that the amount remaining on the crop is so small that when it is eaten, it will be wholesome. Meanwhile, a permitted maximum residue level (MRL) has been set for each of these chemicals and the permitted amounts are extremely low.
2. Radioactive contamination: The radiation and atomic particles emitted from nuclear power stations or nuclear fuel reprocessing plants and from testing of nuclear

weapons are extremely harmful to living cells. Radio isotopes which enter the atmosphere become widely distributed and may finally reach the ground many thousands of miles away, when these radio isotopes fall on soil and vegetation, they may be absorbed by plants when eaten by man, this becomes incorporated into the body tissues with harmful consequences.

3. Contamination from packaging materials: Plastics are increasingly used as packaging materials and while the polymers themselves are non-toxic, compounds which may have been added to them to improve their properties may not be equally safe. These can thereby contaminate foodstuffs by the migration of chemicals from the packaging material. Paper based packaging materials which are widely used for food stuffs could also be a source of contamination.
4. Cross contamination: Cross contamination refers to any contamination caused by an article or already been contaminated object that has already been contaminated. Contamination can be caused by an object like knife, if used to cut through a cow's intestine and the same unwashed knife is used to slice bread, there is cross contamination because the knife has already been contaminated with Escherichia coli organism from the cow's intestine and subsequently used in contaminating the bread. Other examples include polishing a plate with soiled or dirty napkin to serve food, licking of fingers with saliva to pick up paper or foil to wrap snacks.
5. Human Beings and animals: humans are the main reservoir of microorganisms. Sick people should not be allowed to handle foods. People with cold, respiratory disturbances, boils, pimples, acne and infected cuts are good sources of staphylococcus aureus. Nails or mouth of a food service worker could be a source of contamination.
6. Dirty environment/ utensils: if the food preparation area is not hygienically kept it could lead to contamination of food. Also insanitary equipment or utensils are good sources of contamination. E.g. dirty plates, cups, glasses, towels, tables etc.
7. Water: water which is very essential in food production could be a source of food contamination.

8. Air: Microorganisms which can also be found in air could contaminate unprotected foods. The disease-causing organisms may be present in the food preparation area perhaps on the body or clothing of a food service worker. They might be found in floor dust or in the air, in or on the bodies of rodents or insects and possibly in meats or poultry.

3.2.2 Primary sources of microorganisms in food

Bacteria can be found virtually everywhere including humans and can enter food products through different routes. The following list outlines some of the most common ways in which microorganisms enter food products.

Soil, water, and in-plant environment: Many bacteria are carried in soil and water which may contaminate food. Also the in-plant environment is an important source of contamination because of the daily activities and pest infestation. *Listeria, Clostridium, Salmonella,* and *Escherichia* are good examples.

Animal feeds: This is a source of salmonellae to poultry and other farm animals. It is a known source of *Listeria monocytogenes*to dairy and meat animals when fed silage. The organisms in dry animal feed are spread throughout the animal environment and may be expected to occur on animal hides, hair, feathers, etc.

Animal hides: The hide is a source of bacterial contamination of the general environment, hands of establishment employees, and skinned carcasses. Studies have shown that this may be a primary source for *E. coli* O157:H7, *Salmonella*, and *Listeria* in cattle.

Gastrointestinal tract: The intestinal biota consists of many organisms; notable among these are pathogens such as *Salmonella*, *Campylobacter*, *E. coli* O157:H7, and other microorganisms. Any or all of the Enterobacteriaceae may be expected in faeces of livestock and poultry.

Food handlers: The microbiota on the hands and outer garments of handlers generally reflect the environment and habits of individuals (hygiene), and the organisms in question may be those from hides, gastrointestinal tracts, soil, water, dust, and other environmental sources.

Food Utensils: Saws, cutting boards, knives, grinders, mixers, etc. may become contaminated during slaughter and processing operations and ensure a fairly constant level of contamination of meat-borne organisms.

Air and dust: A variety of bacteria may be found in air and dust in food-processing operations at any one time. *Listeria* is an example of a Gram-positive organism that survives in the environment.

Vegetables (plant) and vegetable products: May be a significant concern in the processing of meat, poultry and egg products. A good example is the processing of frozen entrees, salads, etc. containing meat and poultry components. Many or most soil and water organisms contaminate vegetables and fruits.

Globalization of food supply: This is a major factor of contamination resulting in transfer of pathogenic agents between countries (import/export) such as Bovine Spongiform Encephalopathy (BSE) infective agent and *Salmonella* Typhimurium DT104, among others. Also, with the increase in international travel this imposes a risk of introducing pathogens to this country like Foot and Mouth Disease.

Terrorist attacks: There are growing concern in the food industry that terrorist could use pathogens to contaminate food and water supplies in attempt to disrupt the economy, health, and lifestyle among others.

3.2.3 Preventing food contamination

1. Wash and scrub all vegetables carefully, paying particular attention to those intended for use in salads and those to be eaten raw because residuals from chemical sprays may still be present.
2. Correct washing and sanitizing of dishes, eating utensils and any equipment or surfaces which will be in contact with food is absolutely essential.
3. Do not keep chemicals used to destroy pests in food preparation areas
4. Keep fingers away from mouth, lips, face and soiled surfaces

5. Handel no food that can be transferred or picked up with tongs, scoops. Forks, spoons etc. Avoid mixing salads, ground meat etc. with hands
6. Avoid the common use of cups, glasses, towels etc.

SELF-ASSESSMENT EXERCISES

What are the factors that cause:

1. The multiplication of microbial growth

2. The inhibition of microbial growth

4.0. CONCLUSION

Food borne pathogens are the leading causes of illness and death in less-developed countries, killing approximately 1.8 million people. In the developed countries, foodborne pathogens are responsible for so many cases of infectious gastro – intestinal disease each year, hence food safety is a major focus of food microbiology involving the handling, preparation, and storage of food in ways that prevent foodborne illness.

5.0 SUMMARY

Food microbiology is the study of the microorganisms that inhabit, create, or contaminate food. Food microbiology encompasses the study of microorganisms which have both beneficial and deleterious effects on the quality and safety of food. There are basically two parameters that affect the growth of microorganisms in food products, extrinsic and intrinsic. Extrinsic parameters are those properties of the environment (processing and storage) that exist outside of the food product which affect both the foods and their microorganisms. On the other hand, intrinsic parameters, are properties that exist as part of the food product itself, for example, tissues are an inherent part of the animal that may, under a set of conditions, promote microbiological growth.

Food can become contaminated in a multitude of ways and contaminants enter food accidentally or incidentally from the source or farm and end on the table when food is consumed. Some of the ways of avoiding food contamination are: Washing and scrubing all vegetables carefully, correct washing and sanitizing of dishes, eating utensils and any equipment or surfaces which will be in contact with food, Keeping fingers away from mouth, lips, face and soiled surfaces etc.

6.0 TUTOR-MARKED ASSIGNMENT

List the microorganisms that have the following effect:

1. Deleterious effect

2. Beneficial effect

7.0 REFERENCES

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UNIT 4 FOOD BORNE PATHOGENS AND SANITATION

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3.0 main content

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1.0 INTRODUCTION

Food can become contaminated in a multitude of ways and contaminants enter food accidentally or incidentally from the source or farm and end on the table when food is consumed.

Food borne pathogens are the leading causes of illness and death in less developed countries, killing approximately 1.8 million people annually. In developed countries, food borne pathogens are responsible for millions of cases of infectious gastrointestinaldiseases each year, costing billions of money in medical care and lost productivity.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

1. Define the under listed:

a. food borne pathogens

b. food sanitation

2. Discuss at least 5 food pathogens

3. Explain how to promote sanitation in handling food.

3.0 MAIN CONTENT

3.1 Food borne pathogens

There are very many foodborne pathogens; some of them are discussed below;

3.1.1 Enteric viruses

Food and waterborne viruses contribute to a substantial number of illnesses throughout the world. Among those most commonly known are hepatitis A virus, rotavirus, astrovirus, enteric adenovirus, hepatitis E virus, and the human caliciviruses consisting of the noroviruses and the Sapporo viruses. This diverse group is transmitted by the fecal-oral route, often by ingestion of contaminated water and food.

3.1.2 Protozoan parasites

Protozoan parasites associated with food and water can cause illness in humans. Although parasites are more commonly found in developing countries, developed countries have also experienced several foodborne outbreaks. Contaminants may be inadvertently introduced to the foods by inadequate handling practices, either on the farm or during processing of foods. Protozoan parasites can be found worldwide, either infecting wild animals or in water and contaminating crops grown for human consumption. The disease can be much more severe and prolonged in immunocompromissed individuals.

3.1.3 Mycotoxins

Molds produce mycotoxins, which are secondary metabolites that can cause acute or chronic diseases in humans when ingested from contaminated foods. Potential diseases include cancers and tumors in different organs (heart, liver, kidney, and nerves), gastrointestinal disturbances, alteration of the immune system, and reproductive problems. Species of Aspergillus, Fusarium, Penicillium, and Claviceps grow in agricultural commodities or foods and produce the mycotoxins such as aflatoxins, deoxynivalenol, ochratoxin A, fumonisins, ergot alkaloids, T-2 toxin, and zearalenone and other minor mycotoxins such as cyclopiazonic acid and patulin. Mycotoxins occur mainly in cereal grains (barley, maize, rye, and wheat), coffee, dairy products, fruits, nuts and spices. Control of mycotoxins in foods has focused on minimizing mycotoxin production in the field, during storage or destruction once produced. Monitoring foods for mycotoxins is important to manage strategies such as regulations and guidelines, which are used by 77 countries, and for developing exposure assessments essential for accurate risk characterization.

Aflatoxins are still recognized as the most important mycotoxins. They are synthesized by only a few Aspergillus species, of which A. flavus and A. parasiticus are the most problematic. The expression of aflatoxin-related diseases is influenced by factors such as age, nutrition, sex, species and the possibility of concurrent exposure to other toxins. The main target organ in mammals is the liver, so aflatoxicosis is primarily a hepatic disease. Conditions increasing the likelihood of aflatoxicosis in humans include limited availability of food, environmental conditions that favor mold growth on foodstuffs, and lack of regulatory systems for aflatoxin monitoring and control.

3.1.4 Yersinia enterocolitica

Yersinia enterocolitica includes pathogens and environmental strains that are ubiquitous in terrestrial and fresh water ecosystems. Evidence from large outbreaks of yersiniosis and from epidemiological studies of sporadic cases has shown that Y. enterocolitica is a foodborne pathogen. Pork is often implicated as the source of infection. The pig is the only animal consumed by man that regularly harbors pathogenic Y. enterocolitica. An important property of the bacterium is its ability to multiply at temperatures near 0°C, and therefore in many chilled foods. The pathogenic serovars (mainly O: 3, O: 5, 27, O: 8 and O: 9) show different geographical distribution. However, the appearance of strains of serovars O: 3 and O: 9 in Europe, Japan in the 1970s, and in North America by the end of the 1980s, is an example of a global pandemic. There is a possible risk of reactive arthritis following infection with Y. enterocolitica.

3.1.5 Vibrio

Vibrio species are prevalent in estuarine and marine environments, and seven species can cause foodborne infections associated with seafood. Vibrio cholerae O1 and O139 serovtypes produce cholera toxin and are agents of cholera. However, fecal-oral route infections in the terrestrial environment are responsible for epidemic cholera. V. cholerae non-O1/O139 strains may cause gastroenteritis through production of known toxins or unknown mechanism. Vibrio parahaemolytitcus strains capable of producing thermo stable direct hemolysin (TDH) and/or TDH-related hemolysin are most important causes of gastroenteritis associated with seafood consumption. Vibrio vulnificus is responsible for seafood borne primary septicemia, and its infectivity depends primarily on the risk factors of the host. V. vulnificus infection has the highest case fatality rate (50%) of any foodborne pathogen. Four other species (V. mimicus, V. hollisae, V. fluvialis, and V. furnissii) can cause gastroenteritis. Some strains of these species produce known toxins, but the pathogenic mechanism is largely not understood. The ecology of and detection and control methods for all seafood borne Vibrio pathogens are essentially similar.

3.1.6 Staphylococcus aureus

Staphylococcus aureus is a common cause of bacterial foodborne disease worldwide. Symptoms include vomiting and diarrhea that occur shortly after ingestion of S. aureus toxin-contaminated food. The symptoms arise from ingestion of preformed enterotoxin, which accounts for the short incubation time. Staphylococcal enterotoxins are superantigens and, as such, have adverse effects on the immune system. The enterotoxin genes are accessory genetic elements in S. aureus, meaning not all strains of this organism are enterotoxin-producing. The enterotoxin genes are found on prophages, plasmids, and pathogenicity islands in different strains of S. aureus. Expression of the enterotoxin genes is often under the control of global virulence gene regulatory systems.

3.1.7 Campylobacter

Campylobacter spp., primarily C. jejuni subsp. jejuni is one of the major causes of bacterial gastroenteritis in the U.S. and worldwide. Campylobacter infection is primarily a foodborne illness, usually without complications; however, serious sequelae, such as Guillain-Barre Syndrome, occur in a small subset of infected patients. Detection of C. jejuni in clinical samples is readily accomplished by culture and nonculture methods.

3.1.8 Listeria monocytogenes

Listeria monocytogenes is Gram-positive foodborne bacterial pathogen and the causative agent of human listeriosis. Listeria infections are acquired primarily through the consumption of contaminated foods, including soft cheese, raw milk, deli salads, and ready-to-eat foods such as luncheon meats and frankfurters. Although L. monocytogenes infection is usually limited to individuals that are immunocompromised, the high mortality rate associated with human listeriosis makes it the leading cause of death among foodborne bacterial pathogens. As a result, tremendous effort has been made to develop methods for the isolation, detection and control of L. monocytogenes in foods.

3.1.9 Salmonella

Salmonella serotypes continue to be a prominent threat to food safety worldwide. Infections are commonly acquired by animal to human transmission though consumption of undercooked food products derived from livestock or domestic fowl. The second half of the 20th century saw the emergence of Salmonella serotypes that became associated with new food sources (i.e. chicken eggs) and the emergence of Salmonella serotypes with resistance against multiple antibiotics.

3.1.10 Shigella

Shigella species are members of the family Enterobacteriaceae and are Gram negative, nonmotile rods. Four subgroups exist based on O-antigen structure and biochemical properties: S. dysenteriae (subgroup A), S. flexneri (subgroup B), S. boydii (subgroup C) and S. sonnei (subgroup D). Symptoms include mild to severe diarrhea with or without blood, fever, tenesmus and abdominal pain. Further complications of the disease may be seizures, toxic megacolon, reactive arthritis and hemolytic uremic syndrome. Transmission of the pathogen is by the fecal-oral route, commonly through food and water. The infectious dose ranges from 10-100 organisms. Shigella spp. have a sophisticated pathogenic mechanism to invade colonic epithelial cells of the host, man and higher primates, and the ability to multiply intracellularly and spread from cell to adjacent cell via actin polymerization. Shigella spp. is one of the leading causes of bacterial foodborne illnesses and can spread quickly within a population.

3.1.11 Escherichia coli

More information is available concerning Escherichia coli than any other organism, thus making E. coli the most thoroughly studied species in the microbial world. For many years, E. coli was considered a commensal of human and animal intestinal tracts with low virulence potential. It is now known that many strains of E. coli act as pathogens, inducing serious gastrointestinal diseases and even death in humans. There are six major categories of E. coli strains that cause enteric diseases in humans, including the:

1. enterohemorrhagic E. coli, which cause hemorrhagic colitis and hemolytic uremic syndrome,
2. enterotoxigenic E. coli, which induce traveler's diarrhea,
3. enteropathogenic E. coli, which cause a persistent diarrhea in children living in developing countries,
4. enteroaggregativeE. coli, which provokes diarrhea in children,
5. enteroinvasiveE. coli that are biochemically and genetically related to Shigella species and can induce diarrhea,
6. diffusely adherent E. coli, which cause diarrhea and are distinguished by a characteristic type of adherence to mammalian cells.

3.1.12 Clostridium botulinum and Clostridium perfringens

Clostridium botulinum produces extremely potent neurotoxins that result in the severe neuroparalytic disease, botulism. The enterotoxin produced by C. perfringens during sporulation of vegetative cells in the host intestine results in debilitating acute diarrhea and abdominal pain. Sales of refrigerated, processed foods of extended durability including sous-vide foods, chilled ready-to-eat meals, and cook-chill foods have increased over recent years. Anaerobic spore-formers have been identified as the primary microbiological concerns in these foods. Heightened awareness over intentional food source tampering with botulinum neurotoxin has arisen with respect to genes encoding the toxins that are capable of transfer to nontoxigenic clostridia.

3.1.13 Bacillus cereus

The Bacillus cereus group comprises six members: B. anthracis, B. cereus, B. mycoides, B. pseudomycoides, B. thuringiensis and B. weihenstephanensis. These species are closely related and should be placed within one species, except for B. anthracis that possesses specific large virulence plasmids. B. cereus is a normal soil inhabitant, and is frequently isolated from a variety of foods, including vegetables, dairy products and meat. It causes a vomiting or diarrhea illness that is becoming increasingly important in the industrialized world. Some patients may experience both types of illness simultaneously. The diarrheal type of illness is most prevalent in the western hemisphere, whereas the emetic type is most prevalent in Japan. Desserts, meat dishes, and dairy products are the foods most frequently associated with diarrheal illness, whereas rice and pasta are the most common vehicles of emetic illness. The emetic toxin (cereulide) has been isolated and characterized; it is a small ring peptide synthesisednonribosomally by a peptide synthetase. Three types of B. cereus enterotoxins involved in foodborne outbreaks have been identified. Two of these enterotoxins are three-component proteins and are related, while the last is a one-component protein (CytK). Deaths have been recorded both by strains that produce the emetic toxin and by a strain producing only CytK. Some strains of the B. cereus group are able to grow at refrigeration temperatures. These variants raise concern about the safety of cooked, refrigerated foods with an extended shelf life. B. cereus spores adhere to many surfaces and survive normal washing and disinfection (except for hypochlorite and UVC) procedures. B. cereus food borne illness is likely under-reported because of its relatively mild symptoms, which are of short duration.

3.2 Food sanitation

Food sanitation is a series of protocols which are designed to prevent the contamination of food, keeping it safe to eat. Different nations have specific laws in place concerning food sanitation, along with lengthy lists of recommendations from public health agencies. The practice of food sanitation is especially important to people in the food industry, at every step of the supply chain from workers in the fields to waiters at restaurants, but home cooks also need to observe the basics of food sanitation for safety.

3.2.1 Importance of food sanitation

From the moment that food is harvested to the time that it is eaten, it is vulnerable to cross-contamination with bacteria and other substances which could be harmful. The key to food sanitation is keeping food safe and clean, with all of the handlers observing personal hygiene to avoid introducing harmful elements to food, and complying with food sanitation recommendations concerning safe holding temperatures for food, safe cooking temperatures, sterilization of cutting boards and other implements, etc.

At home, common sense precautions like keeping foods frozen or refrigerated before use, washing foods before consumption, washing hands before handling food, cooking or reheating food thoroughly, and using separate cutting boards for meats and vegetables are often sufficient to keep people from getting sick. Certain foods may require additional precautions; people making foods with raw fishes and meats, for example, need to select their ingredients carefully at the store and handle them with special care because bacteria will not be eliminated through cooking.

In the commercial food industry which prepares packaged foods, fast foods in locations like bukaterias, and meals in restaurants, food sanitation can get extremely complex. A single mistake along the sanitation chain could make numerous people sick. If, for example, someone failed to wash his or her hands after using the restroom and then prepared boxed salads for customers of a deli, these customers could get sick from faecal bacteria on the leaves of the salad greens.

Outbreaks of food borne illness due to poor food sanitation are a recurrent problem in many regions of the world. Failure to process foods properly has led to sickness from peanut butter, spinach, hamburger meat, and many other basic staples, and outbreaks have also been traced to restaurants, roadside food stands, and many other locations where food is sold or traded. Even institutions like churches and community bake sales are not exempt from food sanitation issues, making it important for people to remember to use handling precautions every time they come into contact with food.

3.2.2 Food sanitation tips

Following these simple sanitation tips can reduce the chance that you or the people to whom you serve food will suffer from foodborne illnesses.

3.2.2.1 Personal hygiene

-Do not handle food when you are sick.

-Cover cuts, burns, sores, and abrasions with a tight, dry, antiseptic bandage.

-Shower or bathe daily when you are handling food.

-Keep your clothes clean; wear an apron and change it if you wipe your hands on it or it becomes soiled.

-Keep your hair clean and tied back.

-Use soap and plenty of hot water to wash your hands frequently, especially after any act that might contaminate foods.

What sort of acts might contaminate foods? Touching your eyes, mouth, ears, nose or hair, smoking, eating or drinking, using the rest room, sneezing or coughing, using a tissue or handkerchief, handling raw food (such as unwashed fruits or vegetables or uncooked meat), taking out the trash, touching a pet or animal, or touching any dirty surfaces (such as wash cloths, money or credit cards, or soiled dishes or linen).

If you wear food handler gloves, throw them away after each use, or wash your gloved hands as thoroughly as you would wash your bare hands. Gloves can spread germs just as easily as bare hands.

3.2.2 Hygiene in food preparation:

-Keep raw food away from ready-to-eat or cooked food.

-Keep all food away from chemicals.

-Keep cold or frozen foods out of the refrigerator or freezer for as short a time as possible.

-Wash all raw fruits and vegetables before preparation.

-Cover food during preparation.

-When plating food, avoid handling tableware that may touch people¡¦s mouths.

-Never plate food that has touched the floor, unwashed hands, or dirty equipment.

-Always use tongs or scoops when necessary. Wear latex gloves, and never touch prepared food with your hands.

-Wipe up spills promptly.

-Hold food at proper temperatures. Some safe holding temperatures for food are:

-Stuffed meats and reheated leftovers: 165 degrees Fahrenheit (74 degrees Celsius) or above

-Cold food: 40 degrees Fahrenheit (4 degrees Celsius) or below

-Beef and other hot food: 140 degrees Fahrenheit (60 degrees Celsius) or above

-Fish and poultry: 145 degrees Fahrenheit (63 degrees Celsius) or above

-Cooked pork, pork products, hamburgers, and eggs: 155 degrees Fahrenheit (68 degrees Celsius)

Clean and sanitize equipment and utensils after each changed use. This includes knives, cutting boards, and thermometers.

3.2.2.3 Food Storage hygiene:

-Do not refreeze food after it has thawed.

-Always label and date leftovers

-Store raw or thawing meats on the lowest refrigerator shelves

-Store shellfish in the original containers

-Always store food in food-grade containers and food wrap

Most harmful germs thrive in temperatures between 40 and 140 degrees Fahrenheit (4 and 60 degrees Celsius). This is known as the Temperature Danger Zone. However, that number may vary slightly as different health departments vary that amount by plus or minus 5 degrees. When you prepare food, keep it out of the Temperature Danger Zone as much as possible. Note that the Temperature Danger Zone includes room temperature. Whenever a potentially hazardous food (fish, beef, poultry, eggs, dairy products, shellfish, pork, some beans) has been in the Temperature Danger Zone for four hours or more, it should be thrown out.

Salmonella bacteria are the number one cause of foodborne infection. Typical sources of salmonella are meat, poultry, and eggs. Infection can be prevented by cooking food thoroughly and chilling leftovers rapidly.

There are two special methods that can help raise the standards of sanitation in your kitchen. The first is the two-spoon tasting method. Use a clean spoon to scoop up the item you wish to taste. Pour that food into a second clean spoon and then taste it. Never taste food over an open container. This ensures that the spoon you taste from does not go back into the food you are preparing.

The second method is also one of the most effective ways of preventing the spread of germs: hand washing. Wet your hands with hot water and wash your hands and wrists with soap for at least 20 seconds. Scrub your nails with a nail brush. Rinse your hands with hot water for 20 seconds. Follow this procedure twice after using the restroom. Dry your hands using a single-use paper towel or an air dryer. Kitchen towels can retain germs.

The method you use for thawing food is also an integral part of safe food handling. There are three safe ways of thawing frozen food: in a refrigerator, under running water, and in a microwave. Never thaw frozen food at room temperature. It runs the risk of contamination whenever it is left at room temperature.

When thawing frozen food in the refrigerator, remove the food from the freezer. Thaw only the amount of food you need. Place the wrapped food in a shallow container on the lowest shelf of the refrigerator. Do not unwrap the food for thawing. Make sure the refrigerator temperature is cold enough to keep the thawing food cooler than 40 degrees Fahrenheit (4 degrees Celsius). Leave the food in the refrigerator until it is totally thawed. Large amounts of food or food in boxes can take several days to fully thaw in the refrigerator.

When thawing frozen foods under running water, begin by removing only the amount of food you need from the freezer. Make sure the food is tightly wrapped or placed in a watertight container. Place the wrapped food or container under cold running water of 70 degrees Fahrenheit (21 degrees Celsius) or less. Make sure the water does not directly touch the food and that the food does not directly touch the sink. Leave the food under running water until it is completely thawed.

When thawing frozen food in a microwave oven, begin by removing only the amount of food you need from the freezer. Put the food in a microwave-safe container. Adjust the microwave setting according to the manufacturer's instructions. Start the microwave. Thaw food in a microwave oven only in emergencies. Cook food immediately after microwave thawing. Microwave cooking causes food to lose moisture and reduces its quality.

SELF ASSESSMENT EXERCISES

1. Discuss 5 food pathogens
2. How do you store your food in a hygienic way?

4.0 CONCLUSION

When you prepare or handle food that will be eaten, you must be sure you meet the highest standards of sanitation to make sure the food is safe to eat. While these standards are especially important if you work in a food-service operation, they are just as valid in your home kitchen, backyard barbecue, or at an office function.

5.0 SUMMARY

Food can become contaminated in a multitude of ways and contaminants enter food accidentally or incidentally from the source or farm and end on the table when food is consumed. Food borne pathogens are the leading causes of illness and death in less developed countries, killing approximately 1.8 million people annually.

The key to food sanitation is keeping food safe and clean, with all of the handlers observing personal hygiene to avoid introducing harmful elements to food, and complying with food sanitation recommendations concerning safe holding temperatures for food, safe cooking temperatures, sterilization of cutting boards and other implements, etc.

Following simple sanitation tips of personal hygiene, food storage hygiene and food preparation hygiene can reduce the chance that you or the people to whom you serve food will suffer from foodborne illnesses.

6.0 TUTOR-MARKED ASSIGNMENTS

1. Visit a bukateria, a fast food eatery and a high class restaurant and observe their sanitation procedure.

2. Compare and contrast the 3 above

7.0 REFERENCES

Jay, J.M, Loessner, M.J. AND Golden, D.A. (2005) Modern Food Microbiology. Science text Series 7th edition

UNIT 5 TEST KIT FOR BACTERIAL COUNT
(By Ministry of Public Health Thailand)

1.0 Introduction
2.0 Objectives
3.0 Main content
    3.1 Health impact
    3.2 Target sample
    3.3 Grouping of food for tests
    3.4 Procedure
    3.5 Evaluation
    3.6 Procedure after test
4.0 Conclusion
5.0 Summary
6.0 Tutor marked assignment

1.0 INTRODUCTION

Consumption of unclean food can cause gastrointestinal diseases. The quantity of bacterial population in food indicates quality of food. Ministry of Public Health Thailand specified the numbers of bacteria in various kinds of food. At present, the number of bacteria in food have still been found to be in excess of the standard. Therefore, the Department of Medical Sciences has developed test kit for determination of bacterial count in food, which can be used outside the laboratory, and get result within 24 hours.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

1. State the health impact of excess amount of bacteria

2. Identify 10 test foods sampled by the test kit

3. Analyse the 4 groupings of food for testing

4 .Describe the procedure for carrying out the bacterial count using the test kit

3.0 MAIN CONTENT

3.1 Health Impact

Food with excess amount of bacteria may indicated the contamination of food-poisoning bacteria, which can cause diarrhea, nausea, vomiting, fever, headache or even death.

3.2 Target Sample

Ready-to-cook food, raw food. Ready-to-eat food : milk and milk products, ice-cream, sauce, infant food, instant food, vended food, street food, street food, food in restaurant, school, etc.

Number of Tests/Kit

12 Tests

Sensitivity of Test Kit

Lowest detected amount 10 colonies or 10 cells in 1 gram (gm.) of food

Test Kit Tool

A. Tools in Test Kit

- 12 Sachets of test paper (in black envelope)
- 48 Sterile syringes
- 12 Sterile plastic bags
- Reagent 1,2,3 and 4 ; 12 bottles each
- 1 Bag of cotton balls with alcohol
- 1 Bottle of disinfectant
- 1 sheet of test kit manual

B. Other Necessary Tolls

- Balance with 1 gram scale
- Stainless spoon, scissors, and lighter

3.3 Grouping of Food for Tests

- Food under control of Ministry of Public Health's Act

Group 1

- **Sterlized or UHT :** fresh milk, recombined milk, fat-modified milk, flavoured milk, dairy products, modified milk for infant, infant food, and supplementary food for infant
- **Non-sweetened :** condensed milk

For food in Group 1, follow all test procedure except step 5-7

Group 2

Powdered or pasteurized: whole milk, recombined milk, fat-modified milk, flavoured milk, dairy products, modified milk for infant, supplementary food for infant, infant food, cream and ice cream.

- **Sweetened** : condensed milk
- **Instant food :** noodles, vermicelli

- **Sauce:** chili sauce, tomato sauce, and papaya sauce.

For food in Group 2, follow all test procedure except step 6.

Group 3

- **Liquid :** Ice cream
- **Seasoning powder of instant food:** Noodles, vermicelli

For food in Group 3, follow all test procedure except step 7

Group 4

- Ready-to-cook food, raw food, street food, vended food, food stalls, food in restaurant, school, etc.

For food in group 4, follow all test procedure.

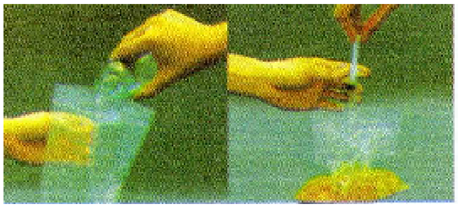
Other foods can request for details at Department of Medical Sciences.

3.4 Procedure

. Examiner uses cotton ball soaked ith alcohol to rub both hands, spoon, issors, and food container at the pening area.

. Use lighter to flame cutting part of issors, hold it to be cooled down and ıt opening area of container. Flame at ɔoon, and hold it to be cooled down.

. Weigh 11 grams of food in a sterile lastic bag.



4. Pour all Reagent 1 in the plastic bag. Tightly close, and vigorously shake at least 25 times. Draw 1 ml. of solution by using a syringe.

5. Inject solution into Reagent 2 bottle. Vigorously shake at least 25 times. Draw 1 ml. of solution by using a new syringe.

6. Inject solution into Reagent 3 bottle. Vigorously shake at least 25 times. Draw 1 ml. of solution by using a new syringe.

7. Inject solution into Reagent 4 bottle. Vigorously shake at least 25 times. Draw 1 ml. of solution by using a new syringe.

8. Touch tip of syringe to test paper in the sachet, and inject all solution.

9. Gently remove air from test paper sachet. Tightly close the sachet. Keep test paper in the dark at room temperature for 24 hours.

3.5Evaluation

Count number of red spot on the test paper, and interpret results as the following table.

Types Of Food	No. of red spot	Interpretation	Bacterial count in 1gm. of food
1. Sterilized: fresh milk, fat-modified milk, recombined milk, flavoured milk, daily products 2. Sterilized: modified milk for infant, infant food	0 1 or > 1	✓ ×	No. of red spot X 10
3. Sterilized: supplementary food for infant 4. Non-sweetened: condensed milk 5. UHT: food in 1, 2, 3	0 – 1 > 1	✓ ×	No. of red spot X 10
6. Pasteurized: Food in 1 at the factory Powdered: food in 2 Sweetened: food in 4 Instant noodles Sauce: chili sauce, tomato sauce, flour, papaya sauce	0 – 1 > 1	✓ ×	No. of red spot X 10,000
7. Instant: rice vermicelli, glass vermicelli 8. Pasteurized: food in 1 when out of factory until expiry date Food in 3: powdered and no boiling needed	0 – 3 > 3 0 – 5 > 5	✓ × ✓ ×	No. of red spot X 10,000
9. Powdered: food in 3 which need boiling, food in 1, cream and ice cream	0 – 10 > 10	✓ ×	
10. Condiments of instant noodles and vermicelli	0 – 5 > 5	✓ ×	No. of red spot X 100,000
11. Ice cream (liquid)	0 – 6 > 6	✓ ×	
12. Ready to eat food: Street food, vended food, food stalls, food in restaurant, school, etc	0 1 or > 1	✓ ×	No. of red spot X 1,000,000
13. Ready-to-cook food, Raw food	0 – 9 10 r > 10	✓ ×	

Note

> = more than, = pass (good quality),   = not pass (poor quality)

- Food in 1-11 are interpreted according to food regulations of The Ministry of Public Health of Thailand.
- Food in 12-13 are interpreted according of food guidelines of Department of Medical Sciences.

3.6 Procedure After Test

Pour disinfectant into the test paper sachet about 1/3 of sachet to destroy microorganisms. Tightly close and discard.

Precaution

- Keep the kit out of reach of children.
- Do not contact disinfectant. Wash immediately if contact any part of the body.
- Beware of using lighter, not close to cotton ball with alcohol.

Keeping/Age

Keep test paper (in black envelope), sterile syringe, plastic bag, and bottles of Reagent 1-4 in refrigerator/ 3 months.

Tightly close bottle of alcohol at all times to prevent evaporation.

4.0 CONCLUSION

It will be a worthwhile exercise if food testing is practice in Nigeria

5.0 SUMMARY

Bear in mind that consumption of unclean food can cause gastrointestinal diseases. Hence food should be tested to ensure that it is safe for consumption.

6**.0 TUTOR-MARKED ASSIGNMENT**

Find out from the ministry of ministry of Health and NAFDAC the types of test kit available in Nigeria

Product by:

Department of Medical Science

Bureau of Quality and Safety of Food

Ministry of Public Health, Thailand

MODULE 2

Unit 1 Overview of microbiology

Unit 2 Microbial growth

Unit 3 Food microbiology

Unit 4 Food borne pathogens and sanitation

Unit 5 Test kit for bacterial count

UNIT 1 FOOD SPOILAGE

Content

1.0 introduction

2.0 objectives

3.0 main content

3.1 what is food spoilage?

3.1.1 signs

3.1.2 causes of food spoilage food

3.1.2.1 natural decay in food

3.1.2.2 the activity of micro-organisms

3.2 reasons for keeping food commodities from spoilage

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1.0 INTRODUCTION

Most natural foods have a limited life. Perishable foods such as fish, meat, milk, bread, tomatoes and potatoes have a short life span. Other foods keep for a considerably longer time but decompose eventually. Once food has been harvested, gathered or slaughtered it begins to deteriorate until eventually it becomes unfit for consumption.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

1. Identify the causes of food spoilage

2. State the reasons for keeping food commodities from spoilage

3. Explain the effects of food spoilage on

a. Protein

b. Fruits and vegetables

3. Fats and oils

3.0 MAIN CONTENT

3.1 What is food spoilage?

Food is considered contaminated when unwanted microorganisms are present. Most of the time the contamination is natural, but sometimes it is artificial. Natural contamination occurs when microorganisms attach themselves to foods while the foods are in their growing stages. For instance, fruits are often contaminated with yeasts because yeasts ferment the carbohydrates in fruits. Artificial contamination occurs when food is handled or processed, such as when faecal bacteria enter food through improper handling procedures.

Food spoilage is a disagreeable change or departure from the food's normal state. Such a change can be detected with the senses of smell, taste, touch, or vision. Changes occurring in food depend upon the composition of food and the microorganisms present in it and result from chemical reactions relating to the metabolic activities of microorganisms as they grow in the food.

3.1.1 Signs

Signs of food spoilage may include an appearance different from the food in its fresh form, such as a change in colour, a change in texture, an unpleasant odour, or an undesirable taste. The item may become softer than normal. If mold occurs, it is often visible externally on the item.

3.1.2 Causes of food spoilage food

Food spoilage is caused by two main factors, namely;

1. Natural decay in foods
2. Contamination by micro-organisms

3.1.2.1 Natural decay in food

This comes about as a result of moisture loss and the action of enzymes.

Moisture loss

Moisture loss mostly occurs in fruit and vegetables which contain large amounts of water. Fruits and vegetables continue to respire after harvesting and therefore lose water through their leaves and skin. Such water could be replaced from the soil through the roots when not harvested. The water retains the structures of the cells of the plants and makes them look fresh. After harvesting, there is no way that the lost water can be replaced so the vegetable or fruit shrinks in size, becomes limp and its skin becomes wrinkled and leathery. Moisture loss occurs in other foods like meat, fish, cheese, due to evaporation of water from the surface.

Enzyme action in the food

Food spoilage can also come about through the action of enzymes presents in the food. Enzymes are chemicals which are present in all food. They speed up chemical changes that result in loss of flavour, colour and texture. As enzymes are mainly composed of protein, they are sensitive to heat. They are active in temperatures found in a kitchen on a warm sunny day. They can remain very slightly active at very low temperatures such as those found in the freezer. This is why there is a limit to the time food can be stored in a freezer. The activity of these enzymes stops when they are heated above 70 ^{o}C. Heat treatment by blanching (i.e. pouring boiling water on the food) is recommended. Some enzymes remain inactive until the food is harvested or slaughtered. Once activated, such enzymes speed up the process of decay by breaking down the tissues and components of the food in the various ways such as oxidation, browning and ripening.

- Oxidation

When Oxidation occurs (i.e. when food comes into contact with oxygen) the enzymes cause the destruction of certain nutrients e.g. vitamin c, thiamine and carotene.

- Browning

Enzymes again cause browning in certain foods the moment they are exposed to air. When you cut or bruise food such as apple or yam, the exposed surface will discolour and turn brownish due to the activity of enzymes.

- Ripening

Enzymes are involved in the process that causes ripening in certain foods such as fruits and vegetables. Unripe bananas for example contain starch which is gradually converted to sugars, until the banana becomes very sweet, and its skin colour changes from green to yellow. Eventually, the skin colour changes to dark brown and it is no longer fit to be consumed.

The activity of enzymes in food makes it easier for the micro-organisms responsible for food spoilage to enter the food.

3.1.2.2 The activity of micro-organisms

The main micro-organisms responsible for the contamination of food are bacteria, moulds and yeasts. These micro-organisms are invisible to the naked eye, but can be seen under a microscope. They are capable of multiplying very rapidly in the correct moisture, food and temperature conditions. These conditions must be avoided if the risk of food spoilage is to be reduced.

- Moulds

Moulds classified as fungi develop a multicellular structure visible to the naked eye. They grow from cells called spores present in the air. They settle and multiply on suitable foods. At this stage, they are visible as a fluffy coloured mass and the food is said to have gone mouldy. Moulds grow most readily in most conditions, at temperatures between 20°C and 40°C. They grow on a variety of foods, particularly meat, cheese, fruit and bread, especially if the food is stored in damp conditions. Moulds may remain active at the low temperatures of a refrigerator but they are destroyed by heat above 70°C. They also like a slightly acid medium and this is why they attack citrus fruits and the surface of jams. Food that is contaminated with mould often appears to be safe to eat as only the outer part is affected by mould growth. However, recent research has shown that substances produced by the mould which migrate into the food could be harmful to many organs of the body. It is therefore advisable to discard mouldy food completely, rather than just to remove the mouldy part.

- Yeasts

Yeasts are microscopic fungi; they are found in the air and soil, and on the surface of fruit. Some are able to tolerate fairly high acidic, salt and sugar concentrations and can grow without the presence of oxygen. The activity of yeast is used in the baking and brewing industries to make bread, doughnut and alcoholic beverages through a process called fermentation. However, they can cause food spoilage in syrups, fruits, fruits juices and jam especially as they can survive without air.

Yeast cells reproduce by budding. At first a small projection appears at the edge of the parent cell and from this cytoplasm and nutrients flow. As the bud grows, the nucleus moves towards it and divides so that a new nucleus enters the bud. When the bud is almost as large as the parent cell, a wall forms separating if from the parent cell, and it then breaks away. When they are reproducing rapidly, the buds do not break away but continue to reproduce until long chains of yeast cells are formed.

Yeast cells grow and reproduce in conditions similar to those required by other fungi. They need oxygen, warmth, food and moisture in order to grow successfully. Yeast grow best at temperatures between 25°C and 30°C. Extreme heat destroys all yeasts and most are destroyed at temperatures above 60°C.

- Bacteria

Bacteria are the most widespread of the micro-organisms found in food. They are minute single cells of various shapes. Under ideal conditions, they divide into two every 20 minutes, consequently, millions of them may develop in contaminated food in a short time. They are more dangerous than moulds and yeast because food may be severely infected but not smell, taste or look bad. Many types of bacteria present are harmless but some do cause illness. The bacteria that cause infections in humans are known as pathogens.

As all bacteria thrive in similar conditions, it is important to avoid conditions which favour their growth in order to prevent infection. They are active over a wide range of temperatures. Some like warmth and are active at $75^{o}C$. Others like cold conditions and grow at temperatures as low as $5^{o}C$. This may cause problems in storage of foods. Some bacteria can form resting bodies called spores to protect them when the conditions are unfavourable for normal growth, for example the wrong degree of acidity or alkalinity, temperature or lack of moisture. Although normal bacteria are destroyed during heat treatment by boiling, some spores survive boiling for hours. They can resume normal activity when conditions become more favourable and contaminate some preserved foods. Bacteria are killed in an acid medium, and therefore they are not a problem in preserving fruits and making jams. The pasteurization of milk does not destroy all bacteria in milk but does destroy those bacteria likely to cause disease. Freezer temperatures must be low enough to prevent bacteria activity during storage. Although some bacteria die in the freezer, some remain inactive in the food and start to grow again when the food thaws. The removal of moisture by drying or by addition of large quantities of sugar and salt make conditions unsuitable for bacteria, and these methods are therefore use in food preservation.

3.2 Reasons for keeping food commodities from spoilage

1. Deterioration may cause food to be wasted
2. Contaminated food can cause illness and in severe cases, this is known as food poisoning
3. Money is saved when food commodities are kept from spoilage
4. When food is kept from spoilage, it maintains it nutritive value
5. It also ensures food is available for use at all times.

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3.3 The effects of spoilage on the various food commodities

- Protein food

They putrify when they are contaminated. This is the situation where protein foods rot, and produce very bad smell.

- Fats and oils

They go rancid. This is the condition where food containing fats and oils begin to smell and taste bad when they are old.

- Carbohydrates

Cooked cereals become marshy and slimy when affected by micro-organisms. This condition is known as serenasis. Flour products smell and taste unpleasant when they are spoilt. They are described as being stale.

- Fruits and vegetables

They rot, ferment and decay.

3.4 Consequences of food spoilage

Some spoiled foods are harmless to eat, and may simply be diminished in quality. But foods exhibiting certain types of spoilage may be harmful to consume. Uncooked or under-cooked animal flesh that spoils is typically quite toxic, and consumption can result in serious illness or death. The toxic effects from consuming spoiled food are known colloquially as "food poisoning", and more properly as "foodborne illness".

3.5 Prevention

A number of methods of prevention can be used that can totally prevent, delay, or otherwise reduce food spoilage.

Preservatives can expand the shelf life of food and can lengthen the time long enough for it to be harvested, processed, sold, and kept in the consumer's home for a reasonable length of time.

Refrigeration can increase the shelf life of certain foods and beverages, though with most items, it does not indefinitely expand it. Freezing can preserve food even longer, though even freezing has limitations.

Canning of food can preserve food for a particularly long period of time, whether canned at home or commercially. Canned food is vacuum packed in order to keep oxygen out of the can that is needed to allow bacteria to break it down. Canning does have limitations, and does not preserve the food indefinitely.

Dried foods can last a long time, sometimes nearly indefinitely.

3.6How to Reduce Spoilage in a Restaurant

With budgets tight, restaurants need to save money whenever and wherever possible. Reducing food spoilage is something that restaurants should be doing, even in a good economy. Here are a few tips to help you keep food spoilage in your restaurant kitchen to a minimum:

1. Avoid over-buying fresh produce. Your sales rep may try to get you to buy several cases of lettuce or tomatoes because they are on sale. However if you won't use more than one case in a week, then you run the risk of food spoilage. And that equals money lost. Only buy sales and special produce you can definitely sell within a week.

2. Keep everything labelled and organized in both your walk-in cooler and freezer as well as in your dry storage. Not only does it ensure food safety, it helps you use older food first (FIFO) before they spoil.

3. Inspect all your food orders when they arrive. Often cases of fresh produce will arrive at your restaurant dead on arrival (DOA). That is, they are either spoiled or about spoilt. Send back the orders in such cases and speak with your sales rep. If this happens repeatedly, it is time to start shopping for a new food vendor.

4. Keep beer and wine at constant temperatures. Even though beer and wine are not fresh, per se, they are still perishable. Fluctuating temperatures can cause beer to have a “skunked” taste and makes wine bitter. So make sure your dry storage area, or wherever you store your beer and wine, is set at a constant temperature.

Food spoilage is almost impossible to escape in a restaurant. But you can minimize it by staying organized and only buying what you need. However, don’t get overzealous about tossing questionable foods. Remember the golden rule "*When in doubt, throw it out*!" A little spoilage is better than risking your customer’s health.

SELF ASSESSMENT EXERCISES

Leave some bread, oranges and paw-paw on the shelf for 7 days and observe what happens

4.0 CONCLUSION

However, it is important to remember that some of the conditions that accelerate spoilage, such as *inappropriate temperature and moisture control*, also encourage the growth of pathogenic microorganisms that cause foodborne illness. Consequently, spoiled food is not just an issue of quality; it is also often a question of food safety.

5.0 SUMMARY

Food is considered contaminated when unwanted microorganisms are present. Most of the time the contamination is natural, but sometimes it is artificial. Food spoilage is a disagreeable change or departure from the food's normal state. Such a change can be detected with the senses of smell, taste, touch, or vision. Changes occurring in food depend upon the composition of food and the microorganisms present in it.

Signs of food spoilage may include an appearance different from the food in its fresh form, such as a change in colour, a change in texture, an unpleasant odour, or an undesirable taste.

Food spoilage is caused by two main factors, namely;

1. Natural decay in foods
2. Contamination by micro-organisms

Some spoiled foods are harmless to eat, and may simply be diminished in quality. But foods exhibiting certain types of spoilage may be harmful to consume. Uncooked or under-cooked animal flesh that spoils is typically quite toxic, and consumption can result in serious illness or death.

A number of methods of prevention can be used that can totally prevent, delay, or otherwise reduce food spoilage.

6.0 TUTOR-MARKED ASSIGNMENT

Take small raw portions of the following food items: oranges, fish, bananas, pepper, tomatoes and meat. Leave them on the shelf for 5 days.

A. Observe what happens to each of them

B. Describe how each of them finally looks, smells and taste like in a tabular form

7.0 REFERENCES

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UNIT 2 MEAT AND FISH SPOILAGE

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1.0 INTRODUCTION

Meat and fish are considered to be spoiled when they become unfit for human consumption. A variety of factors can cause meat and fish to spoil including micro-organisms, exposure to air, and improper freezing techniques. Spoiled meat and fish may be inedible due to unpleasant tastes and odours or may be unsafe for consumption especially when micro-organisms have caused the meat to spoil. In this unit, you shall learn how meat and fish go bad so you can use the knowledge to get the best out of them.

2.0 OBJECTIVES

At the end of this unit, you shall be able to:

1. Identify the indicators for meat storage and their causes

2. Describe the spoilage of:

a. Fresh fish

b. Processed fish

3.0 MAIN CONTENT

3.1 Spoilage

Spoilage is the degradation of food such that the food becomes unfit for human consumption. Food can be spoiled by a number of means, including physical and chemical means. However, the most prevalent cause of food spoilage is microbial growth and residence in the food, which results in numerous undesirable metabolites being produced in the food that cause unwanted flavours and odours. The main microbial organisms responsible for food spoilage are known as specific spoilage organisms (SSOs). The concept of SSOs arises from the fact that not all bacteria cause food spoilage; indeed, the degree of food spoilage is not proportional to the amount of microbes present on the food. SSOs are solely responsible for spoilage of the food and the typical characteristics associated with that spoilage. They are typically present in very low numbers and comprise a low percentage of the microflora present on the food.

3.2 Meat Spoilage by Bacteria, Yeasts, and Molds

Although a number of factors may contribute to meat spoilage, the most common cause of meat spoilage is the deterioration of meat caused by micro-organisms (bacteria, yeasts, and molds). Foods can contain dangerous bacteria and microorganisms but still have a normal appearance. Food which has not been handled or stored properly should not be eaten even if it has no apparent indications of spoilage. The table below shows some of the common indications that meat has spoiled.

Indication of Spoilage	Cause
Ammonia or sulfur smell, bad odour, tallow or chalky taste.	Degradation of proteins, lipids (fats) and carbohydrates caused by bacteria and/or enzymes naturally present in meat.
Slime formation, bad odour and rancid flavour, colour change (such as grey, brown, or green)	Bacterial and yeast spoilage
Sticky meat surface	Mold spoilage

"Whiskers"	Mold spoilage
Surface colourations such as creamy, black or green	Growth of mold colonies
Tainting, souring, and putrefacation	Anaerobic bacterial spoilage of meat interiors, vacuum packed products, and sealed containers

3.3 Other Types of Spoilage

There are factors other than micro-organisms which can cause meat to spoil. They results from improper handling of meat.

Indication of Spoilage	Cause
Oxidative Rancidity (rancid flavour and odour)	Oxidation of meat fats due to improperly wrapped meat.
Brown or grey discolouration	Protein denaturation caused by heat, salts, ultraviolet light, low pH, and surface

	dehydration
Dehydration and discolouration during freezing resulting in dryness of cooked meat, nutrient loss, and sometimes a bitter flavour.	Freezer burn and drip which occurs during slow freezing.
Absorption of Off-Flavours	Storage of meat next to foods such as apples and onions which give off strong odours

3.4 Fish spoilage

Fish spoilage manifests itself physically in so many ways. In terms of smell, spoiled fish will generally have a fishy, sour, or ammonia-like stench. Appearance-wise, spoiled fish may appear to be dry or mushy in certain areas, and the gills may have slime. Spoiled fish will also have flesh that is soft, or does not spring back when pressed upon. Typically, spoiled fish will also have a green or yellowish discolouration; however, this arises not from spoilage metabolites, but rather oxidation of the oxygen transporters in fish blood (myoglobin to metamyoglobin) during frozen storage or from prolonged or unnecessary exposure of the fish to air.

Compared to other foods, fish is unique as a substrate for microbial growth. This uniqueness stems from several important factors: the poikilotherm nature of fish, a high post mortem pH in the flesh (typically greater than 6.0), the presence of non-protein-nitrogen (NPN) in large quantities, and the presence of trimethylamine oxide (TMAO).

The poikilotherm nature of fish selects for bacteria that can thrive in a wide range of temperatures. For example, the microflora of temperate water fish is dominated by psychrotrophic Gram-negative, rod-shaped bacteria such as those found in the genera *Pseudomonas* and *Moraxella*, with only varying proportions of Gram-positive organisms such as *Bacillus*.

The high post mortem pH of fish flesh is caused by the fact that fish flesh is low in carbohydrates (less than 0.5%) in the muscle tissue and that only small amounts of lactic acid are produced after death. This allows pH sensitive organisms such as *Shewanella putrefaciens* to grow in seafood but not in other meats.

The NPN fraction of the fish flesh consists of low-molecular-weight water-soluble nitrogen compounds, particularly free amino acids and nucleotides, that allow it to serve as a readily available bacterial growth substrate. Decomposition of these compounds is responsible for many of the off-odours and off-flavours typically found in spoilage. For example, the breakdown of cysteine and methionine by certain microbes, both sulfur-containing amino acids, forms hydrogen sulfides and methylmercaptane respectively which causes undesirable odours to emanate from spoiled fish.

The presence of TMAO in fish is well-established, and it is known to cause a high redox potential in the fish flesh, although the significance of this is not clear. The spoilage of fish is influenced most by the presence of TMAO in conditions where oxygen is not present. Some anaerobic bacteria are able to utilize TMAO as the terminal electron acceptor in an anaerobic respiration process with trimethylamine (TMA) as the primary product; TMA contributes to the characteristic ammonia-like and fishy off-flavours in spoiled fish.

3.4.1 Spoilage of fresh fish

Microbes are found on the outer body covering and the inner surfaces of fresh fish, such as the skin, gills, and GI tract. The poikilotherm nature of fresh fish allows a wide variety of bacteria to grow, including the Gram-negative, rod-shaped bacteria which belong to the genera *Pseudomonas*, *Moraxella*, *Acinetobacter*, *Shewanella*, *Flavobacterium*, *Aeroemonadaceae*, and *Vibrionaceae*, and Gram-positive bacteria such as *Bacillus*, *Micrococcus*, *Clostridium*, *Lactobacillus*, and *Corynebacterium*. Psychrotrophs are bacteria that can tolerate cold temperature and grow at 0 degree Celsius but grow optimally around 25 degrees Celsius.

At the time of being captured, fresh fish contain on their bodies a wide variety of microorganisms, also known as the microflora of the fish. Depending on the region of water from which the fish are caught, the microflora of the fish can have different degrees of complexity. For example, fish that are caught in very cold and clean waters have a lower number of psychrotrophic and psychrophilic microbes whereas fish caught in warmer waters have somewhat higher counts of mesophilic microbes. In addition, fish captured from polluted warm water have a selection of unique microbes due to the presence of a large number of *Enterobacteriaceae*. However, regardless of where the fish has been caught, only a number of the microbes is able to proliferate on the post-mortem fish. Of these surviving microbes, only a small portion can generate metabolites that create the off-flavours, off-odours and discolourations that humans find unsuitable for consumption. In fresh fish, the specific spoilage bacteria include *Shewanella putrefaciens* and *Pseudomonas spp.*

The immune system of alive or newly caught fish can be deadly to the spoilage bacteria *S. putrefaciens* and *Pseudomonas spp.* since the immune system of the fish is still functional and keeps the flesh of the fish sterile by suppressing the growth of bacteria in that location. However, post-mortem, the immune system deteriorates. Without the immune system barrier, some bacteria invade the flesh by entering between the muscle fibers while others establish colonies on the flesh. As the fish body breaks down, some metabolic biomaterials make their way to the surface and become available to the microbes *S. putrefaciens* and *Pseudomonas spp.*

Since fish are typically put on ice immediately post-harvest, *S. putrefaciens* and *Pseudomonas spp.* often pass through a lag phase of approximately one to two weeks in order to adjust to the new environment. How long the lag phase lasts depends on how long the bacteria need to make the appropriate biosynthetic materials and prepare for growth. After these processes have been complete, *S. putrefaciens* and *Pseudomonas spp.* enter the exponential phase, in which it grows at an exponential rate. Over time, communities of these microbes are established that produce various metabolites that are associated with spoilage.

In dead fresh fish, enzymes can bring about the destruction of cells via autolytic changes. Both *S. putrefaciens* and *Pseudomonas spp.* can produce hypoxanthine from inosine or inosine monophosphate which come from the autolytic changes in dead fish and use them as biosynthetic materials to grow.

For fresh chilled fish stored in air, *Pseudomonas spp.* typically produce biogenic amines, ketones, aldehydes, esters, sulfur compounds. *S. putrefaciens* typically produce TMA, H2S, acetic acid, and other sulfur compounds. *S. putrefaciens* can use trimethylamine oxide (TMAO) as the terminal electron acceptor to generate TMA. This is an anaerobic respiration process that helps *S. putrefaciens* generate energy in the form of ATPs via the Kreb's cycle. Due to the very small amount of carbohydrate that most fish contain (less than 0.5% of body composition), very small amounts of lactic acid are produced, making the pH on the body of post-mortem fresh fish usually above 6.0 which is appropriate for the growth of the pH-sensitive bacteria *S. putrefaciens* . Furthermore, breakdown of certain amino acids on fresh fish also establishes an appropriate environment for bacteria to proliferate. For example, the breakdown of amino acids such as glycine, serine, and leucine help the bacteria gain esters, ketones, and aldehydes for its metabolism.

In general, without further preservation techniques, the environment of a fresh fish provides an abundance of biosynthetic materials that the spoilage organisms such as *Shewanella putrefaciens* and *Pseudomonas spp.* can readily use to survive and proliferate. The products of metabolic processes of these microbes include biological compounds that signal spoilage and render the fish unsuitable for human consumption.

3.4.2 Processed fish

The spoilage activity of lightly preserved fish and fish products may develop in spite of the inhibitory strength of the processing and storage conditions. The microorganisms living off the food products have evolved and managed to endure the physical and chemical processing techniques, including CO_2 and vacuum packing, salting, heating or pasteurization, and addition of preservatives. Numerous studies have identified several SSOs including *Photobacterium phosphoreum* and lactic acid bacteria (*Lactobacillus* and *Carnobacterium*) which are largely responsible for spoilage of lightly preserved products.

SELF ASSESSMENT EXERCISES

Purchase some small quantities of meat and fish and observe them under different conditions.

4.0 CONCLUSION

Meat and fish are excellent sources of nourishment; care should therefore be taken in handling them so that they do not become sources of infection.

5.0 SUMMARY

Meat and fish are considered to be spoiled when they become unfit for human consumption. A variety of factors can cause meat and fish to spoil including micro-organisms, exposure to air, and improper freezing techniques. Spoilage is the degradation of food such that the food becomes unfit for human consumption. Food can be spoiled by a number of means, including physical and chemical means. However, the most prevalent cause of food spoilage is microbial growth and residence in the food, which results in numerous undesirable metabolites being produced in the food that cause unwanted flavours and odours. Although a number of factors may contribute to meat spoilage, the most common cause of meat spoilage is the deterioration of meat caused by micro-organisms (bacteria, yeasts, and molds). Microbes are found on the outer body covering and the inner surfaces of fresh fish, such as the skin, gills, and GI tract. The poikilotherm nature of fresh fish allows a wide variety of bacteria to grow, including the Gram-negative, rod-shaped bacteria which belong to the genera *Pseudomonas*, *Moraxella*, *Acinetobacter*, *Shewanella*, *Flavobacterium*, *Aeroemonadaceae*, and *Vibrionaceae*, and Gram-positive bacteria such as *Bacillus*, *Micrococcus*, *Clostridium*, *Lactobacillus*, and *Corynebacterium*. Psychrotrophs are bacteria that can tolerate cold temperature and grow at 0 degree Celsius but grow optimally around 25 degrees Celsius.

6.0 TUTOR MARKED ASSIGNMENTS

Review the preservation of meat and fish and suggest the best food preserving methods in terms of cost,product quality and health

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UNIT 3 SPOILAGE OF FRUITS AND VEGETABLES

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1.0 INTRODUCTION

Contamination may take place during harvesting, handling, transportation or storage unless proper hygienic conditions are maintained. Mechanical damage may increase the susceptibility to decay and the growth of microorganisms may take place. Washing process in contaminated water may moisten surfaces enough to permit entry and growth of organisms. Storage in contaminated containers, use of contaminated dressing materials, possible contact with decayed products, unhygienic handling, fly infestation etc. will also cause an accelerated rate of spoilage.

2.O OBJECTIVES

At the end of this unit, you should be able to:

1. Identify at least 10 most common types of microbial spoilage.2. Describe at least 5 moulds responsible for post-harvest disease of fruits

3. Analyse the type of fungi causing the important spoilage of fresh and stored vegetables

4. Describe the yeast spoilage of fresh fruits and vegetables

3.0 MAIN CONTENT

3.1 Spoilage of fruits and vegetables

It is estimated that one-fourth of the harvested fruits and vegetables is spoiled before consumption. Spoilage of fresh fruits and vegetables usually occurs during storage and transport. Vegetables and fruits reach the consumer as fresh, dried, frozen, fermented, pasteurized, or canned.

The deterioration of raw vegetables and fruits may result from physical factors, action of their enzymes, microbial action, or combinations of all these. Microbial spoilage in fruits and vegetables varies not only with the kind of fruit or vegetables but also to some extent with the variety. Microbial spoilage may due to:

(1) plant pathogens acting on stems, leaves, flowers, or root of the plant, on the fruit or other special parts used as foods;

(2) saprophytic organisms, which may be secondary invaders after the action of plant pathogen or may enter a healthy fruit or vegetable, as in the case of various rots or grow on its surface, as when bacteria multiply on moist, piled vegetables. Sometimes, a saprophyte may succeed the pathogen or a succession of saprophytes may be involved in the spoilage.

3.2 Commonly occurring microbial spoilage

The most commonly occurring types of microbial spoilage in fruits and vegetables are as follows:

1. **Bacterial soft rot**, caused by *Erwinia crtatowa* and related species, which are fermenters of pectins, *Pseudomonas marginalis,Clostridium* and *Bacillus* spp. Have also been associated with these rots. It results in water-soaked appearance, a soft, mushy consistency, and often a bad odour.

2. **Gray mould rot**: caused by species of Botrytis, eg: *B.cinerea*, which is favored by high humidity and warm temperature.

3. **Rhizopus soft rot**: caused by species Rhizopus, eg *R.stolonifer*. A rot results that often is soften and mushy. The cottony growth of the mould with small, black dots of sporangia often covers masses of the foods.

4. **Anthracnose**, usually caused by *Colletotrichum lindemuthianum, C. coccodes* and other species. The defect is a spotting of leaves and fruit or seedpods.

5. **Alternaria rot**, caused by *Alternaria tenuis* and other species. Areas become greenish-brown early in the growth of the mould and later turn to brown or black spots.

6. **Blue mould rot**: caused by species of *Penicilfium digitatum* and other species. The bluish-green colour that gives the rot its name results from the masses of spores of the mould.

7. **Downy mildew**, caused by species of *Phytophthora*, *Bremia*, and other genera. The moulds grow in white, woolly masses.

8. **Watery soft rot** caused chiefly by *Sclerotinia sclerotiorum,* is found mostly in vegetables.

9. **Stem-end rots**, caused by species of moulds of several genera, e.g., *Diplodia, Alternaria, Phomopsis, Fusarium*, and others, involve the stem ends of fruits.

10. **Black mould rot**, caused by *Aspergillus niger*. The rot gets its name from the dark-brown to black masses of spores of the mould, termed "smut".

11. **Black rot**, often caused by species of *Alternaria* but sometimes of *Cera?tostomella, Physalospora,* and other genera.

12. **Pink mould rot**, caused by pink-spored *Trichothecium roseum.*

*13.***Fusarium rots**, a variety of types of rots caused by species of *Fusarium.*

14. **Green mould rot**, caused usually by species of *Cladosporium* but sometimes by other green-spored moulds, e.g., *Trichoderma.*

15. **Brown rot**, caused chiefly by Sclerotinia (*Monilinia fructicola*) species.

16. **Sliminess** or **souring**, caused by saprophytic bacteria in piled, wet, heating vegetables.

3.3 Fungal spoilage

Fungal spoilage of vegetables often results in water-soaked, mushy areas, while fungal rots of fleshy fruits such as apples and peaches frequently show brown or cream-coloured areas in which mould mycelia are growing in the tissue below the skin and aerial hyphae and spores may appear later. Some types of fungal spoilage appear as "**dry rots**," where the infected area is dry and hard and often discoloured. Rots of juicy fruits may result in leakage.

The composition of the fruit or vegetable influences the likely type of spoilage. Thus, bacterial soft rot is widespread for the most part among the vegetables, which are not very acid. Thus the character of the spoilage will depend on the product attacked and the attacking organism.

3.4 SOME OF THE MORE IMPORTANT MOULDS RESPONSIBLE FOR POST-HARVEST DISEASES OFFRUITS

Genus	Spoilage Problems
Alternaria	Brown to black spots on apples, stone fruitsand figs; stem-end and black rot of citrus fruits. [Stone fruits include cherries, peaches, nectarines, apricots and plums]
Aspergillus	Black rot on peaches, nectarines, apricots, citrus fruits and figs
Botryodiplodia	Cushion or crown rot of bananas; ripe rot of pawpaws
Botrytis	Grey mould rot of apples, pears, raspberries, strawberries, grapes, figs, blueberries, citrus and stone fruits
Cladosporium	Restricted rot with grey black core on stone fruits, olive-green growth on raspberries, black rot on grapes and spotting of figs.
Colletotrichum	Brown to black spots (anthracnose) on citrus fruits, avocados, mangoes, pawpaws and papayas
Diplodia	Stem-end rot of citrus fruit, avocados, mangoes and papayas; watery, tan-brown rot of peaches
Fusarium	Brown rot of citrus fruit and pineapple; soft rot of figs
Geotrichum	Sour rot of citrus fruits and peaches
Gloeosporium	Anthracnose, black rot and lesion rot of bananas; eye rot of pome fruits [Pome fruits include apples, pears and quince]
Monilinia	Brown rot of stone fruits
Mucor	Soft rot of strawberries, pears
Nigrospora	Soft, watery (squirter) rot of the pulp of bananas
Penicillium	Blue and green mould rots of citrus fruits; blue mould rot of apples, grapes, pears, stone fruits

	and figs; brown rot of pineapples
Phomopsis	Stem-end rot of citrus fruits and avocados
Phytophthora	Brown rot of apples and citrus fruits, leathery rot of strawberries
Rhizopus	Watery, soft rot of apples, pears, stone fruits, grapes, strawberries, avocados and figs
Trichoderma	Cocoa-brown to green rot of citrus fruits

3.5 GENERA OF FUNGI CAUSING IMPORTANT SPOILAGE OF FRESH AND STORED VEGETABLES

Examples of Commodities Most Affected	**Genus**	***Type of Spoilage***
Most vegetables especially carrot, lettuce, celery, cabbage	Botrytis	Grey mould rot
Most vegetables. Especially carrot, lettuce, legumes, Brassica spp.	Sclerotinia	Watery soft rot
Legumes, carrot, Brassica spp.	Rhizopus	Soft rot
Tomato, cucumber, asparagus, potato	Fusarium	Dry rots
Tomato, potato, carrot	Phytophthora	Brown rots (blight)
Tomato, potato, beetroot	Phoma	Dry brown, black rots
Cucumber, legumes, potato	Pythium	Cottony leak
Onion, Brassica spp.	Peronospora	Downy mildews
Tomato, Brassica spp	Alternaria	Firm, black rots

3.6 YEAST SPOILAGE OF FRESH FRUITS AND VEGETABLES

Dates	Saccharomyces spp. Hanseniaspora valbvensis Candida quilliermandii
Figs	Hanseniaspora uvarum (Klorkera apiculata) Hanseniaspora valbvensis Torulopsis stellata Saccharomyces cerevisiae Candida krusei
Strawberries	Kloekera apiculata
Tomatoes	Hanseniaspora uvarum (K. apiculata) Pichia kluvveri Nematospora corvli
Legumes Coffee berries Citrus fruits Nuts	Nematospora corvli
Pineapple	Candida spp.
Rhubarb	Trichosporon cutaneum

3.7 YEAST SPOILAGE OF PROCESSED FRUITS AND VEGETABLES

a. Salt-brined Vegetables Sauerkraut	Discolouration	Saccharomyces cerevisiae Torulopsis holmii Candida krusei
Cucumbers	"Bloaters"	Brettanomyces spp. T. holmii Hansenula subpelliculosa Sacch. Rosei Sacch. Rouxii
	Surface films	Debaryomyces spp.
Olives	Softening	Rhodotorula glutinis Rh. Minuta Rh. Rubra Sacch. Oleaginosus Sachh. Kluvveri
b. Acetic Acid Preserves Onions Gherkins Red beetroot Red cabbage Piccalilli Sauces	Gas Pockets	Hansenula anomala
	Gas formation	Zygosaccharomyces bailii
	Off odours Surface films	Pichia membranaefaciens
c. Mayonnaise-based Salads Coleslaw	Off odour Gas production	Sacch. 75xiguous Sacch. Dairensis

Potato salad	Gas production	Sacch. 76xiguous Sacch. Dairensis Pichia membranaefaciens
Mixed vegetable and frusalads	Gas production Off odour	Saccharomyces spp.

3.8 BACTERIA THAT CAUSE SOFT ROT OF VEGETABLES AND FRUIT

	Temperatures for Growth (°C)			
Bacterium	**Min**	**Opt**	**Max**	**Produce Affected**
Erwinia carotovora subsp. atroseptica	3	27	35	Most vegetables, particularly potatoes, some fruit
Erwinia carotovora subsp. carotovora	6	28-30	37-42	Most vegetables and somefruit
Erwinia chrysanthemi	6	34-37	>45	Pineapple
Pseudomonas marginalis	>0.2	25-30	>41	Many vegetables
Pseudomonas viridiflava	-	-	-	Beans
Psedomonas cichorii	-	c. 30	>41	Chicory, endive, cabbage, lettuce

SELF ASSESSMENT EXERCISES

State the ways fruits and vegetables can be preserved

4.0 CONCLUSION

Spoilage of fruits and vegetables occurs anytime during harvesting, handling, storage and transportation, the onus therefore lies on you the consumer to make wise choices when making your purchase.

5.0 SUMMARY

It is estimated that one-fourth of the harvested fruits and vegetables is spoiled before consumption. Spoilage of fresh fruits and vegetables usually occurs during storage and transport. The deterioration of raw vegetables and fruits may result from physical factors, action of their enzymes, microbial action, or combinations of all these. Microbial spoilage in fruits and vegetables varies not only with the kind of fruit or vegetables but also to some extent with the variety. Most commonly occurring types of microbial spoilage are bacterial soft rot, blue mould rot anthracasedowny mildew etc. Fungal spoilage of vegetables often results in water-soaked, mushy areas, while fungal rots of fleshy fruits such as apples and peaches frequently show brown or cream-coloured areas in which mould mycelia are growing in the tissue below the skin and aerial hyphae and spores may appear later. Thus the character of the spoilage will depend the product attacked and the attacking organism. So many types of moulds are responsible for post-harvest diseases of fruits. Fungi like grey mould rot and watery soft rot affect most vegetables especially carrots and cabbage, dry rots affect tomatoes, cucumber etc, yeast like nomatospora corvi spoil tomatoes, legumes and citrus fruits.

6.0 TUTOR MARKED ASSIGNMENT

1. Visit 3 fruit and vegetable stalls and take note of all the fruits and vegetables available.

2. Take note of the appearance of:

a. The wholesome ones

b. The unwholesome ones meant to be discarded

Report the differences in

- colour

- Appearance

- Smell

7.0 REFERENCES

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UNIT 4 FOOD PRESERVATION

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1.0 INTRODUCTION

The greatest threat to the quality and safety of our food comes from microbial spoilage. Food is a valuable source of nutrients for certain microbes. As they grow on the food, they may cause problems such as bad taste, unpleasant smell and poor appearance. More importantly, the growth of microbes may lead to dangerous levels of toxins in the food. This makes the food unfit to be eaten. In this unit, we shall learn about food preservation and the methods of preserving foods

2.0 OBJECTIVES

At the end of this unit you shall be able to:

- Define the term 'food preservation' and state its need.
- Explain the basic principles of food preservation.
-List and describe at least 12 methods of food preservation;

- Describe recipes for preservation of simple food items at home.

3.0 MAIN CONTENT

3.1 What is food preservation?

Food preservation is the process of treating and handling food to stop or slow down spoilage (loss of quality, edibility or nutritional value) and thus allow for longer storage.

Preservation usually involves preventing the growth of bacteria, yeasts, fungi, and other micro-organisms (although some methods work by introducing benign bacteria, or fungi to the food), as well as retarding the oxidation of fats which cause rancidity. Food preservation can also include processes which inhibit visual deterioration (when something becomes less closer to the original) that can occur during food preparation; such as the enzymatic browning reaction in apples after they are cut.

Many processes designed to preserve food will involve a number of food preservation methods. Preserving fruit, by turning it into jam, for example, involves boiling (to reduce the fruit's moisture content and to kill bacteria, yeasts, etc.), sugaring (to prevent their re-growth) and sealing within an airtight jar (to prevent recontamination). There are many traditional methods of preserving food that limit the energy inputs and reduce carbon footprint.

Maintaining or creating nutritional value, texture and flavour is an important aspect of food preservation, although, historically, some methods drastically altered the character of the food being preserved. In many cases these changes have now come to be seen as desirable qualities – cheese, yoghurt and pickled onions are common examples.

3.2 Methods of food preservation

Food preservation methods are intended to keep microorganisms out of foods, remove microorganisms from contaminated foods, and hinder the growth and activity of microorganisms already in foods.

To keep microorganisms out of food, contamination is minimized during the entire food preparation process by sterilizing equipment, sanitizing it, and sealing products in wrapping materials. Microorganisms may be removed from liquid foods by filtering and sedimenting them or by washing and trimming them. Washing is particularly valuable for vegetables and fruits, and trimming is useful for meats and poultry products.

3.2.1 Drying

Drying is one of the most ancient food preservation techniques, which reduces water activity sufficiently to prevent or delay bacterial growth.

3.2.2 Refrigeration

Refrigeration preserves food by slowing down the growth and reproduction of micro-organisms and the action of enzymes which cause food to rot. The introduction of commercial and domestic refrigerators drastically improved the diets of many in the Western world by allowing foods such as fresh fruit, salads and dairy products to be stored safely for longer periods, particularly during warm weather.

3.2.3 Freezing

Freezing is also one of the most commonly used processes commercially and domestically for preserving a very wide range of food including prepared food stuffs which would not have required freezing in their unprepared state. For example, potato waffles are stored in the freezer, but potatoes themselves require only a cool dark place to ensure many months' storage. Cold stores provide large volume, long-term storage for strategic food stocks held in case of national emergency in many countries.

3.2.4 Vacuum packing

Vacuum-packing stores food in a vacuum environment, usually in an air-tight bag or bottle. The vacuum environment strips bacteria of oxygen needed for survival, slowing spoiling. Vacuum-packing is commonly used for storing nuts to reduce loss of flavour from oxidation.

3.2.5 Salting

Salting or curing draws moisture from the meat through a process of osmosis. Meat is cured with salt or sugar, or a combination of the two. Nitrates and nitrites are also often used to cure meat and contribute the characteristic pink colour, as well as inhibition of Clostridium botulinum.

3.2.6 Sugaring

Sugar is used to preserve fruits, either in syrup with fruit such as apples, pears, peaches, apricots, plums or in crystallized form where the preserved material is cooked in sugar to the point of crystallisation and the resultant product is then stored dry. This method is used for the skins of citrus fruit (candied peel), angelica and ginger. A modification of this process produces glacé fruit such as glacé cherries where the fruit is preserved in sugar but is then extracted from the syrup and sold, the preservation being maintained by the sugar content of the fruit and the superficial coating of syrup. The use of sugar is often combined with alcohol for preservation of luxury products such as fruit in brandy or other spirits. These should not be confused with fruit flavoured spirits such as cherry brandy or Sloe gin.

3.2.7 Smoking

Smoking is used to lengthen the shelf life of perishable food items. This effect is achieved by exposing the food to smoke from burning plant materials such as wood. Most commonly subjected to this method of food preservation are meats and fish that have undergone curing. Fruits and vegetables like paprika, cheeses, spices, and ingredients for making drinks such as malt and tea leaves are also smoked, but mainly for cooking or flavouring them. It is one of the oldest food preservation methods, which probably arose after the development of cooking with fire.

3.2.8 Artificial food additives

Preservative food additives can be *antimicrobial*; which inhibit the growth of bacteria or fungi, including mold, or *antioxidant*; such as oxygen absorbers, which inhibit the oxidation of food constituents. Common antimicrobial preservatives include calcium propionate, sodium nitrate, sodium nitrite, sulfites (sulfur dioxide, sodium bisulfite, potassium hydrogen sulfite, etc.) and disodium EDTA. Antioxidants include BHA and BHT. Other preservatives include formaldehyde (usually in solution), glutaraldehyde (kills insects), ethanol and methylchloroisothiazolinone.

3.2.9 Pickling

Pickling is a method of preserving food in an edible anti-microbial liquid. Pickling can be broadly categorized as chemical pickling for example, In chemical pickling, the food is placed in an edible liquid that inhibits or kills bacteria and other micro-organisms. Typical pickling agents include brine (high in salt), vinegar, alcohol, and vegetable oil, especially olive oil but also many other oils. Many chemical pickling processes also involve heating or boiling so that the food being preserved becomes saturated with the pickling agent. Common chemically pickled foods include cucumbers, peppers, corned beef, herring, and eggs, as well mixed vegetables such as piccalilli.

In fermentation pickling, the food itself produces the preservation agent, typically by a process that produces lactic acid. Fermented pickles include sauerkraut, nukazuke, kimchi, surströmming, and curtido. Some pickled cucumbers are also fermented.

3.2.10 Lye

Sodium hydroxide (lye) makes food too alkaline for bacterial growth. Lye will saponify fats in the food, which will change its flavour and texture. Lutefisk uses lye in its preparation, as do some olive recipes. Modern recipes for century eggs also call for lye. Masa harina and hominy use agricultural lime in their preparation and this is often misheard as 'lye'.

3.2.11 Canning and bottling

Canning involves cooking food, sealing it in sterile cans or jars, and boiling the containers to kill or weaken any remaining bacteria as a form of sterilization. Foods have varying degrees of natural protection against spoilage and may require that the final step occur in a pressure cooker. High-acid fruits like strawberries require no preservatives to can and only a short boiling cycle, whereas marginal fruits such as tomatoes require longer boiling and addition of other acidic elements. Low acid foods, such as vegetables and meats require pressure canning. Food preserved by canning or bottling is at immediate risk of spoilage once the can or bottle has been opened.

Lack of quality control in the canning process may allow ingress of water or micro-organisms. Most such failures are rapidly detected as decomposition within the can causes gas production and the can will swell or burst. However, there have been examples of poor manufacture (underprocessing) and poor hygiene allowing contamination of canned food by the obligate anaerobe*Clostridium botulinum*, which produces an acute toxin within the food, leading to severe illness or death. This organism produces no gas or obvious taste and remains undetected by taste or smell. Its toxin is denatured by cooking, though. Cooked mushrooms, handled poorly and then canned, can support the growth of Staphylococcus aureus, which produces a toxin that is not destroyed by canning or subsequent reheating.

3.2.12 Jellying

Food may be preserved by cooking in a material that solidifies to form a gel. Such materials include gelatine, agar, maize flour and arrowroot flour. Some foods naturally form a protein gel when cooked such as eels and elvers, and sipunculid worms which are a delicacy in the town of Xi amen in Fuji a province of the People's Republic of China. Jellied eels are a delicacy in the East End of London where they are eaten with mashed potatoes. Potted meats in aspic, (a gel made from gelatine and clarified meat broth) were a common way of serving meat off-cuts in the UK until the 1950s. Many jugged meats are also jellied.

3.2.13 Irradiation

Irradiation of food is the exposure of food to ionizing radiation; either high-energy electrons or X-rays from accelerators, or by gamma rays (emitted from radioactive sources as Cobalt-60 or Caesium-137). The treatment has a range of effects, including killing bacteria, molds and insect pests, reducing the ripening and spoiling of fruits, and at higher doses inducing sterility. The technology may be compared to pasteurization; it is sometimes called 'cold pasteurization', as the product is not heated. Irradiation is not effective against viruses or prions, it cannot eliminate toxins already formed by microorganisms, and is only useful for food of high initial quality.

The radiation process is unrelated to nuclear energy, but it may use the radiation emitted from radioactive nuclides produced in nuclear reactors. Ionizing radiation is hazardous to life (hence its usefulness in sterilisation); for this reason irradiation facilities have a heavily shielded irradiation room where the process takes place. Radiation safety procedures ensure that neither the workers in such facility nor the environment receive any radiation dose from the facility. Irradiated food does not become radioactive, and national and international expert bodies have declared food irradiation as wholesome. However, the wholesomeness of consuming such food is disputed by opponents and consumer organizations. National and international expert bodies have declared food irradiation as 'wholesome'; UN-organizations as WHO and FAO are endorsing to use food irradiation. International legislation on whether food may be irradiated or not varies worldwide from no regulation to full banning. Irradiation may allow lower quality or contaminated foodstuffs to be rendered marketable.

It is estimated that about 500,000 tons of food items are irradiated per year worldwide in over 40 countries. These are mainly spices and condiments with an increasing segment of fresh fruit irradiated for fruit fly quarantine.

3.2.14 Pulsed electric field processing

Pulsed electric field (PEF) processing is a method for processing cells by means of brief pulses of a strong electric field. PEF holds potential as a type of low temperature alternative pasteurization process for sterilizing food products. In PEF processing, a substance is placed between two electrodes, then the pulsed electric field is applied. The electric field enlarges the pores of the cell membranes which kills the cells and releases their contents. PEF for food processing is a developing technology still being researched. There have been limited industrial applications of PEF processing for the pasteurization of fruit juices.

3.2.15 Modified atmosphere

Modifying atmosphere is a way to preserve food by operating on the atmosphere around it. Salad crops which are notoriously difficult to preserve are now being packaged in sealed bags with an atmosphere modified to reduce the oxygen (O_2) concentration and increase the carbon dioxide (CO_2) concentration. There is concern that although salad vegetables retain their appearance and texture in such conditions, this method of preservation may not retain nutrients, especially vitamins. Grains may be preserved using carbon dioxide by one of two methods; either using a block of dry ice placed in the bottom and the can is filled with grain or the container can be purged from the bottom by gaseous carbon dioxide from a cylinder or bulk supply vessel.

Carbon dioxide prevents insects, and depending on concentration, mold, and oxidation from damaging the grain. Grain stored in this way can remain edible for five years.

Nitrogen gas (N_2) at concentrations of 98% or higher is also used effectively to kill insects in grain through hypoxia. However, carbon dioxide has an advantage in this respect as it kills organisms through hypercarbia and depending on concentration hypoxia and, requiring concentrations of above 35%, or so. This makes carbon dioxide preferable for fumigation in situations where a hermetic seal cannot be maintained.

Air-tight storage of grains (sometimes called hermetic storage) relies on the respiration of grain, insects and fungi which can modify the enclosed atmosphere sufficiently to control insect pests. This is a method of great antiquity, as well as having modern equivalents. The success of the method relies on having the correct mix of sealing, grain moisture and temperature.

3.2.16 High pressure food preservation

High pressure food preservation refers to high pressure used for food preservation. "Pressed inside a vessel exerting 70,000 pounds per square inch (480 MPa) or more, food can be processed so that it retains its fresh appearance, flavour, texture and nutrients while disabling harmful microorganisms and slowing spoilage. By 2005 the process was being used for products ranging from orange juice to guacamole to deli meats and widely sold.

3.2.17 Burial in the ground

Burial of food can preserve it due to a variety of factors: lack of light, lack of oxygen, cool temperatures, pH level, or desiccants in the soil. Burial may be combined with other methods such as salting or fermentation. Most foods can be preserved in soil that is very dry and salty (thus a desiccant), or soil that is frozen.

Many root vegetables are very resistant to spoilage and require no other preservation than storage in cool dark conditions, for example by burial in the ground, such as in a storage clamp. Century eggs are created by placing eggs in alkaline mud (or other alkaline substance) resulting in their "inorganic" fermentation through raised pH instead of spoiling. The fermentation preserves them and breaks down some of the complex, less flavourful proteins and fats into simpler more flavourful ones. Cabbage was traditionally buried in the fall in northern farms in the USA for preservation. Some methods keep it crispy while other methods produce sauerkraut.A similar process is used in the traditional production of kimchi. Sometimes meat is buried under conditions which cause preservation. If buried on hot coals or ashes, the heat can kill pathogens, the dry ash can desiccate, and the earth can block oxygen and further contamination. If buried where the earth is very cold, the earth acts like a refrigerator.

3.2.18 Controlled use of micro-organism

Some foods, such as many cheeses, wines, and beers will keep for a long time because their production uses specific micro-organisms that combat spoilage from other less benign organisms. These micro-organisms keep pathogens in check by creating an environment toxic for themselves and other micro-organisms by producing acid or alcohol. Starter micro-organisms, salt, hops, controlled (usually cool) temperatures, controlled (usually low) levels of oxygen and/or other methods are used to create the specific controlled conditions that will support the desirable organisms that produce food fit for human consumption.

3.2.19 Biopreservation

Some lactic acid bacteria manufacture nisin. It is a particularly effective preservative

Biopreservation is the use of natural or controlled microbiota or antimicrobials as a way of preserving food and extending its shelf life. Beneficial bacteria or the fermentation products produced by these bacteria are used in biopreservation to control spoilage and render pathogens inactive in food. It is a benign ecological approach which is gaining increasing attention.

Of special interest are lactic acid bacteria (LAB). Lactic acid bacteria have antagonistic properties which make them particularly useful as biopreservatives. When LABs compete for nutrients, their metabolites often include active antimicrobials such as lactic and acetic acid, hydrogen peroxide, and peptidebacteriocins. Some LABs produce the antimicrobial nisin which is a particularly effective preservative.

These days LAB bacteriocins are used as an integral part of hurdle technology. Using them in combination with other preservative techniques can effectively control spoilage bacteria and other pathogens, and can inhibit the activities of a wide spectrum of organisms, including inherently resistant Gram-negative bacteria.

3.2.20 Hurdle technology

Hurdle technology is a method of ensuring that pathogens in food products can be eliminated or controlled by combining more than one approach. These approaches can be thought of as "hurdles" the pathogen has to overcome if it is to remain active in the food. The right combination of hurdles can ensure all pathogens are eliminated or rendered harmless in the final product.

Hurdle technology has been defined by Leistner (2000) as an intelligent combination of hurdles which secures the microbial safety and stability as well as the organoleptic and nutritional quality and the economic viability of food products. The organoleptic quality of the food refers to its sensory properties, that is its look, taste, smell and texture.

Examples of hurdles in a food system are high temperature during processing, low temperature during storage, increasing the acidity, lowering the water activity or redox potential, or the presence of preservatives or biopreservatives. According to the type of pathogens and how risky they are, the intensity of the hurdles can be adjusted individually to meet consumer preferences in an economical way, without sacrificing the safety of the product.

Principal hurdles used for food preservation

Parameter	Symbol	Application
High temperature	F	Heating
Low temperature	T	Chilling, freezing
Reduced water activity	a_w	Drying, curing, conserving
Increased acidity	pH	Acid addition or formation
Reduced redox potential	E_h	Removal of oxygen or addition of ascorbate
Biopreservatives		Competitive flora such as microbialfermentation
Other preservatives		Sorbates, sulfites, nitrites

SELF –ASSESSMENT EXERCISES

State the differences between the traditional and modern methods of food preservation

4.0 CONCLUSION

Preserved food not only adds variety to our meals but also helps in utilizing excess produce at harvest time.

5.0 SUMMARY

Food preservation is the process of treating and handling food to stop or slow down spoilage (loss of quality, edibility or nutritional value) and thus allow for longer storage. Many processes designed to preserve food will involve a number of food preservation methods. Preserving fruit, by turning it into jam, for example, involves boiling (to reduce the fruit's moisture content and to kill bacteria, yeasts, etc.), sugaring (to prevent their re-growth) and sealing within an airtight jar (to prevent recontamination). Food preservation methods are intended to keep microorganisms out of foods, remove microorganisms from contaminated foods, and hinder the growth and activity of microorganisms already in foods. Drying, smoking, freezing, canning, bottling, refrigeration, salting etc are some of the food preservation methods.

6.0 TUTOR-MARKED ASSIGNMENTS

1. There are a lot of preserved foods available in the market. List 10 of them and state approximate shelf life of each.
2. Also, state if there are any instructions about keeping each.
3. State one reason for doing so?

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UNIT 5 FOOD ADDITIVES

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1.0 INTRODUCTION

Food additives have been used for centuries. Food preservation began when man first learned tosafeguard food from one harvest to the next and by the salting and smoking of meat and fish. TheEgyptians used colours and flavourings, and the Romans used saltpetre (potassium nitrate), spicesand colours for preservation and to improve the appearance of foods. Cooks regularly used baking powder as a raising agent, thickeners for sauces and gravies, and colours, such as cochineal, to transform good-quality raw materials into foods that were safe, wholesome and enjoyable to eat.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

1. Define food additives

2. Identify at least 20 food items that contain food additives

3. Classify food additives

3.0 MAIN CONTENT

3.1 What are food additives and why are they necessary?

A food additive is defined as "any substance not normally consumed as a food in itself and notnormally used as a characteristic ingredient of food whether or not it has nutritive value, the intentional addition to food for a technological purpose in the manufacture, processing, preparation, treatment, packaging, transport or storage of such food results, or may be reasonablyexpected to result, in it or its by-products becoming directly or indirectly a component of suchfoods".

Many food additives are naturally occurring and some are even essential nutrients; it is the technicalpurpose that leads to these being classified as food additives and given an E number.

3.1.1 Why Use Additives?

Many people enjoy making bread, cakes, wine, beer, and ice cream at home. However, most of today's food is bought from shops and supermarkets. Food made at home is always at its best when eaten straight away. Food produced on the large scale that is needed to supply supermarkets and other food shops has to be transported and stored before it is consumed. It has to stay in top condition over amuch longer period of time than home-cooked food.

Additives are used so that these foods still have a consistently high quality. In some products, they areso essential that additives are used even in certain organic foods.

In some countries, lots of food is lost because it 'goes off' due to microbial growth before it can be eaten. Food poisoning also shows the dangers of contaminated food and without the use of preservatives,it would quite likely be more common.

Preservatives, colours and flavours are the best known additives but in fact there are many categoriesof additives, each tailored to a specific purpose.

Food additives play an important role in today's complex food supply. Never before has therange and choice of foods been so wide either in supermarkets, specialist food shops or when eating out.

Whilst a shrinking proportion of the population is engaged in primary food production, consumers are demanding more variety, choice and convenience alongside higher standards of safety and wholesomeness at affordable prices. Meeting these consumer expectations can onlybe achieved using modern food processing technologies which include the use of a variety of foodadditives proven effective and safe through long use and rigorous testing.

Additives carry out a variety of useful functions which we often take for granted. Foods are subjectedto many environmental conditions, such as temperature changes, oxidation and exposure to microbes,which can change their original composition. Food additives play a key role in maintaining the foodqualities and characteristics that consumers demand, keeping food safe, wholesome and appealing fromfarm to fork. Food additives are very carefully regulated and the general criteria for their use is thatthey perform a useful purpose, are safe and do not mislead the consumer.

3.1.2 How is the safety of food additives evaluated?

All food additives must have a demonstrated useful purpose and undergo a rigorous scientific safety Evaluation before they can be approved for use. Until the creation of the European Food SafetyAuthority (EFSA), the safety evaluation of additives in Europe was done by the Scientific Committeeon Food (SCF). At present, it is the EFSA Panel on Food Additives, Flavourings, Processing Aidsand Materials in Contact with Food (AFC Panel), who is in charge of this task. In Nigeria, theStandards organisation of Nigeria (SON) and National Agency For Food and Drug AdministrationAnd Control (NAFDAC) are charged with the responsibility. At an international level there is a JointExpert Committee, from the Food and Agriculture Organisation (FAO) and the World HealthOrganisation (WHO), on Food Additives (JECFA).

The Codex Alimentarius Commission, a joint FAO/WHO activity which develops guidelines for food safety globally, is also drawing up new "General Standards for Food Additives" (GSFA), with the aimof establishing a harmonised, workable and indisputable international standard for world trade. Onlythose additives that have been evaluated by the JECFA are included.

As a result of strict regulation and thorough testing, food additives can be considered safe components in our diet that are contributing to the rapid evolution of the food supply in Europe and throughout the world.

3.2 Do food additives cause allergies or food intolerance reactions?

There has been much public concern that additives cause adverse reactions although careful investigations show that this is often based on misconception rather than on identifiable adverse reactions.

Food additives have only rarely been shown to cause true allergic (immunological) reactions. Among the food additives reported to cause adverse reactions are:

3.2.1 Colours

Reactions to tartrazine (E 102, a yellow food colour) and carmine (E 120 or red cochinille) have been reported occasionally in sensitive individuals. Symptoms include skin rashes nasal congestion and hives, although the incidence is very low (estimated to be 1-2 persons per 10,000) and very rare. Ig E-mediatedallergic reactions have been reported for carmine. Tartrazine has also been reported to cause asthma in sensitive individuals although the incidence is extremely low.

3.2.2 Sulphites

One group of additives that can cause problems in sensitive individuals is the sulfiting agents. This group includes several inorganic sulphite additives (E 220-228), including sodium sulphite, potassium bisulphite and metabisulphite containing sulphur dioxide (SO2). These preservatives are used to control microbial growth in fermented beverages and they have been widely used in wines, beers and fruit products for over 2000 years. In sensitive (asthmatic) individuals, sulphites may trigger asthma characterised by breathing difficulties, shortness of breath, wheezing and coughing.

3.2.3 Monosodium glutamate (MSG) and aspartame

MSG is made up of sodium and glutamic acid. Glutamic acid is an amino acid found naturally in high protein foods such as meats and dairy products like Camembert cheese. MSG is also a flavour enhancer used in prepared meals, some Chinese food, certain sauces and soups. MSG has been "blamed" for a variety of side effects including headaches and body tingling, however scientific studies show no link between MSG and these reactions suggesting that some other component of the meal, or even psychological responses, may be responsible for any adverse effects.

Similarly, the high-intensity sweetener aspartame (another substance made from naturally occurring amino acids, aspartic acid and phenylalanine) has been blamed for a wide variety of adverse effects, none of which have been validated by scientific studies.

While food additives pose no problems for most people, a small number of people with specific allergies may be sensitive to certain food additives. It appears that where food additives have an adverse effect, they exacerbate a pre-existing condition rather than induce it. These adverse reactions, which are rarely allergic, and the foods or food components responsible, should be validated by a health professional or dietician to ensure that unnecessary dietary restrictions are not imposed. As all food additives are clearly labelled, those with specific sensitivities and those who believe they have sensitivity to a food additive,can readily avoid any that may pose problems.

3.3 Common food additives

Food additives that are commonly added to foods include:

3.3.1 Additives that maintain freshness and prevent deterioration

Some food additives help to keep foods fresh and safe. They help increase shelf-life by protectingfoods against deterioration caused by oxidation or by micro-organisms. They can be divided into two categories based on their principal function.

3.3.1.1 Antioxidants

Oxidation reactions happen when chemicals in the food are exposed to oxygen in the air. In natural conditions, animal and plant tissues contain their own antioxidants but in foods, these natural systems break down and oxidation is bound to follow.

Oxidation of food is a destructive process, causing loss of nutritional value and changes in chemical composition. Oxidation of fats and oils leads to rancidity and, in fruits such as apples, it can result in the formation of compounds which discolour the fruit.

Antioxidants are added to food to slow the rate of oxidation and, if used properly, they can extend the shelf life of the food in which they have been used.

3.3.1.1.1 Oxidation of Fats

Fats and oils, or foods containing them, are the most likely to have problems with oxidation. Fats react with oxygen and even if a food has a very low fat content it may still need the addition of an antioxidant.
They are commonly used in:

- vegetable oil
- snacks (extruded)
- animal fat
- meat, fish, poultry
- margarine
- dairy products
- mayonnaise / salad dressing
- baked products
- potato products (instant mashed potato)

As the fat decomposes and reacts with oxygen, chemicals called peroxides are produced. These change into the substances characteristic of the smell and soapy flavour of a rancid fat. Antioxidants prevent the formation of peroxides and so slow the process of the food 'going off'. Some antioxidants react with oxygen itself and so prevent the formation of peroxides.

Air-tight packaging, using inert gases like nitrogen, vacuum packing and refrigeration can all be used to delaythe oxidation process. However, these can still be inefficient and adding antioxidants can be an effective way of extending the shelf life of a product.

Antioxidants prevent the oxidation of foods that results rancidity or discolouration. They are used in baked foods, cereals, fats, oils and salad dressings. The major fat soluble antioxidants are:

Tocopherols (E 306-309), BHA (butylated hydroxyanisole or E 320) and BHT (butylated hydroxytolueneor E 321) - these protect edible fats, vegetable oils and salad dressings from turning rancid.

- Ascorbic acid (E 300) and citric acid (E 330) - which preserve the colour of freshly cut fruits and vegetables.

3.3.1.2. Preservatives

Most preservatives today are actually fungistatic in their action. That means they prevent the growth offungi, moulds and yeasts. They have little effect on bacteria but using a combination of preservatives, with antibacterial properties, can give food all round protection. Food preservatives help to control the spread of bacteria which can cause life threatening illnesses such as salmonellosis or botulism.

Preservatives limit, retard or arrest the growth of micro-organisms (e.g. bacteria, yeast, mould) that arepresent in or gain entry to the food, preventing spoilage or food poisoning. They are used in baked foods, wine, cheese, cured meats, fruit juices and margarine among others. Preservatives are commonly used in these foods:

- low fat spreads
- cheeses, margarine, mayonnaise and dressings
- bakery products
- dried fruit preparations

Examples include:

Sulphur dioxide and sulphites (E 220-228) - these help to prevent colour changes in dried fruits and vegetables. Sulphites also inhibit the growth of bacteria in wine and fermented foods, some snack foods and baked goods. Sulphites also have antioxidant properties.

Calcium propionate (E 282) - prevents bread and baked foods from turning mouldy. Nitrates and nitrites (sodium and potassium salts) (E 249-252) - are used as a preservative in processed meats such as ham and frankfurters to keep the products safe by preventing the growth of botulinum bacteria, Clostridium botulinum, which is highly pathogenic.

Are Preservatives Safe?

Preservatives have to be safe for human consumption. They can stop the food-decay microbes from growing but must not harm the cells of the human body. There are also maximum levels of preservatives allowed, so that high concentrations of preservatives in food are not permitted.

There is much concern about the increasing incidence of the phenomenon of resistance of bacteria to antibiotics. Over the decades in which preservatives have been used, there has been noneed to increase the dosage to maintain their effectiveness. This suggests that the use of these substanceshas not resulted in the development of bacteria that are resistant to preservatives.

3.3.1.3 Additives that amplify or promote sensory qualities

Additives are also useful for imparting certain characteristics to foods, improving texture or helping in food processing.

3.3.1.3.1. Taste and texture modifiers

Examples are:
Emulsifiers and stabilisers - The purpose of these food additives is to maintain consistent texture and to prevent the separation of ingredients in such products as margarine, low-fat spreads, ice cream, salad dressings and mayonnaise. Many reduced-fat and low-fat versions of common foods are dependent on this technology. Any recipe that requires the mixing of ingredients that normally do not mix, such as fat and water, need emulsifiers and stabilisers to impart and maintain the desired consistency. Examples include lecithin, mono- and digycerides.

Emulsifiers have a big effect on the structure and texture of many foods. They are used to aid in the processing of foods and also to help maintain quality and freshness. In low fat spreads, emulsifiers can helpto prevent the growth of moulds which would happen if the oil and fat separated. The table shows foods in which emulsifiers are most commonly used.

Foods that Commonly Contain Emulsifiers

Biscuits	Toffees	Bread
Extruded snacks	Chewing gum	Margarine / low fat spreads
Breakfast cereals	Frozen desserts	Coffee whiteners
Cakes	Ice-cream	Topping powders
Desserts / mousses	Dried potato	Peanut butter
Soft drinks	Chocolate coatings	Caramels

Thickeners - these substances help increase the viscosity of foodstuffs. They are added to foods such as salad dressings and flavoured milk. Gelatin or pectin are often used as thickening agents.
Gelling agents gel foods, i.e. they give shape and structure Thickeners or thickening agents make foods thicker.
Stabilisers help to maintain the physical and textural properties of foodstuffs through their production, transport, storage and cooking
Sweeteners - Both "bulk" and "intense" sweeteners impart a sweet taste to foodstuffs and are useful in low-calorie products and for special dietary products, such as those for diabetics.

Intense sweeteners, such as acesulfam K (E 950), aspartame (E 951) and saccharin (E 954) are 130-200 times, 200 times and 300-500 times sweeter, respectively, than sugar-and they have zero calories. Thaumatin (E 957), a naturally sweet protein extracted from the fruit of the plant Thaumatococcus danielli, is 2500 times sweeter than sugar and is used at very low levels for its flavouring properties. Bulk sweeteners include sorbitol (E 420), isomalt (E 953) and maltitol (E 965) and these can be incorporated into "table-top" sweeteners and in energy-reduced foods, in which they provide volume and mouth feel. These substances have reduced caloric value, providing 2.4 kcal/gram compared with 4 kcal/gram for other carbohydrates.
Flavour enhancers - Probably the best known is monosodium glutamate (MSG; E 621), which is used to bring out and enhance the flavours in the foods to which it is added. It is used mainly in savoury products and in a wide variety of oriental dishes.

Others - this group includes acids, acidity regulators (used to control acidity and alkalinity in various types of food products), anti-caking agents (used to keep powders flowing freely), anti-foaming agents (reduce foams, e.g. when jams are boiled), and packaging gases (used in certain types of sealed packages, such as for meat, fish, seafood and ready-prepared vegetables and salads found in chill cabinets).

3.3.1.3.2. Colours

Colour is one of the first and most important sensory qualities and it helps us to accept or reject particular foods. Whilst adding colour may appear to some to be purely cosmetic, there is no doubt that colour is important in consumer perception of a food and it is often associated with a specific flavour and intensity of flavour.
Colours are used to add or restore colour in a food in order to enhance its visual appeal and to match consumer expectations. The processing of peas and the preparation of jams can lead to loss of colour, and hence food colours can compensate for these losses. Some colours are used purely for visual decoration on cakes and confectionery items. Masking or disguising inferior quality, however, are unacceptable uses of colours.

The primary reasons for adding colours to foods include:

- To offset colour loss due to exposure to light, air, extremes of temperature, moisture and storage conditions
- To compensate for natural or seasonal variations in food raw materials or the effects of processing and storage to meet consumer expectations (Masking or disguising inferior quality, however,are unacceptable uses of colours.).
- To enhance colours that occur naturally but at levels weaker than those usually associated with a given food.

E Number	Name	Description	Foods
E100	Curcumin	Orange-yellow colour that is extracted from the roots of the turmeric plant.	Curry, fats and oils, processed cheese.
E101	Riboflavin	Riboflavin is also known as	Sauces, processed cheese and foods with

		vitamin B2. It can be obtained by fermenting yeast or synthesised artificially. In foods, it is used as an orange-yellow colour.	added vitamins such as bread.
E102	Tartrazine	Yellow coloured synthetic azo dye. Colouring sparks controversy as some groups suggest it causes behavioural problems in children (see food issues).	This is no longer widely used. Now rarely used in curries and some ready-meals.
E160a	Beta-carotene	Orange-yellow colour found in plants such as carrots, tomatoes and oranges.	Soft drinks, margarine, butter, yoghurt.
E150a	Plain caramel	Dark brown to black colour. The most common colouring. 90% of all colouring used is caramel. Obtained by the heating of sugars.	Cola drinks, confectionery, baked-foods, ice cream, chocolate, beers, vinegar and whisky.
E123	Amaranth	Dark purple coloured synthetic colour. Similar in colour to blackcurrants.	Powdered soup, jam, ice cream, instant gravy.

SELF –ASSESSMENT EXERCISES
Suggest 5 reasons why additives are important in this modern life

4.0 CONCLUSION

The use of food additives is an emotional topic which continues to provoke consumer concern.Over the last
50 years, developments in food science and technology have led to the discovery of many new substances
that can fulfill numerous functions in foods. These food additives are now readily available and include; emulsifiers in margarine, sweeteners in low-calorie products and a wider range of preservatives and antioxidants which slow product spoilage and rancidity whilst maintaining taste.

5.0 SUMMARY

A food additive is defined as "any substance not normally consumed as a food in itself and not normally
used as a characteristic ingredient of food whether or not it has nutritive value, the intentional addition of which to food for a technological purpose in the manufacture, processing, preparation, treatment, packaging, transport or storage of such food results, or may be

reasonably expected to result, in it or its by-products becoming directly or indirectly a component of such foods"

Food additives play an important role in today's complex food supply. Additives carry out a variety of useful functions which we often take for granted. Foods are subjected to many environmental conditions, such as temperature changes, oxidation and exposure to microbes, which can change their original composition.
Food additives play a key role in maintaining the food qualities and characteristics that consumers demand, keeping food safe, wholesome and appealing from farm to fork. Food additives are very carefully regulated and the general criteria for their use is that they perform a useful purpose, are safe and do not mislead the consumer.

All food additives must have a demonstrated useful purpose and undergo a rigorous scientific safety evaluation before they can be approved for use. The Codex Alimentarius Commission, a joint FAO/WHO activity which develops guidelines for food safety globally, is also drawing up new "General Standards
for Food Additives" (GSFA), with the aim of establishing a harmonised, workable and indisputable international standard for world trade. Only those additives that have been evaluated by the JECFA are included.

As a result of strict regulation and thorough testing, food additives can be considered safe components in
our diet that are contributing to the rapid evolution of the food supply in Europe and throughout the world.
Food additives that are commonly added to foods include:
Anioxidants e.g.Tocopherol,ascorbic acid,citric acid.
Preservatives: Examples include:
Sulphur dioxide and sulphites (E 220-228) - these help to prevent colour changes in dried fruits and vegetables. Sulphites also inhibit the growth of bacteria in wine and fermented foods, some snack foods
and baked goods. Sulphites also have antioxidant properties.
Calcium propionate (E 282) - prevents bread and baked foods from turning mouldy.

Nitrates and nitrites (sodium and potassium salts) (E 249-252) - are used as a preservative in processed
meats such as ham and frankfurters to keep the products safe by preventing the growth of botulinum
bacteria, Clostridium botulinum, which is highly pathogenic.
Taste and texture modifiers, e.g. thickeners, stabilizers, emulsifiers etc.

6.0 TUTOR-MARKED ASSIGNMENTS

1. Pay a visit to at least 3 supermarkets in your state and make a list of at leastt 20 food items that containadditives

2. Classify the additives into:
    a. Additives that promote freshness and prevent deterioration
    b. Additives that amplify or promote sensory qualities

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MODULE 3

Unit 1 Fermentation
Unit 2 Microorganism used in food and beverages preparation
Unit 3 Fermented foods

UNIT 1 FERMENTATION

Content

1.0 introduction

2.0 objectives

3.0 main content

3.1 fermentation defined

3.2 uses

3.3 list of fermented foods

3.4 fermented foods from round the world

3.5 fermented foods by type

3.5.1 bean-based

3.5.2 grain-based

3.5.3 vegetable based

3.5.4 fruit based

3.5.5 honey based

3.5.6 dairy based

3.5.7 fish based

3.5.8 meat based

3.5.9 tea based

4.0 conclusion

5.0 summary

6.0 tutor - marked assignments

7.0 references

1.0 INTRODUCTION

Fermentation is one of the oldest forms of food preservation technologies in the world. Indigenous fermented foods such as bread, cheese and wine, have been prepared and consumed for thousands of years and are strongly linked to culture and tradition, especially in rural households and village communities.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

1. State at least 5 benefits of fermentation

2. Analyse fermented food and beverage by food type and by country

3. Identify at least 10 Nigerian fermented foods and beverages

3.0 MAIN CONTENT

3.1 Fermentation defined

Fermentation is the "slow decomposition process of organic substances induced by micro-organisms, or by complex nitrogenous substances (enzymes) of plant or animal origin". It can be described as a biochemical change, which is brought about by the anaerobic or partially anaerobic oxidation of carbohydratesby either micro-organisms or enzymes. This is distinct from putrefaction, which is the degradation of protein materials. Fermentation in food processing typically is the conversion of carbohydrates to alcohols and carbon dioxide or organic acids using yeasts, bacteria, or a combination thereof, under anaerobic conditions. Fermentation in simple terms is the chemical conversion of sugars into ethanol. The science of fermentation is also known as, zymology or zymurgy.

Fermentation usually implies that the action of microorganisms is desirable, and the process is used to produce alcoholic beverages such as wine, beer, and cider. Fermentation also is employed in the leavening of bread (CO_2 produced by yeast activity); in preservation techniques to produce lactic acid in sour foods such as sauerkraut, dry sausages, kimchi, and yogurt; and in pickling of foods with vinegar (acetic acid).

Fermentation is a relatively efficient, low energy preservation process which increases the shelf life and decreases the need for refrigeration or other form of food preservation technology. It is therefore a highly appropriate technique for use in developing countries and remote areas where access to sophisticated equipment is limited. Fermented foods are popular throughout the world and in some regions they make a significant contribution to the diet of millions of individuals.

Natural fermentation precedes human history. Since ancient times, however, humans have been controlling the fermentation process. The earliest evidence of winemaking dates from eight thousand years ago, in Georgia, in the Caucasus area. Seven-thousand-year-old jars containing the remains of wine have been excavated in the Zagros Mountains in Iran, which are now on display at the University of Pennsylvania. There is strong evidence that people were fermenting beverages in Babylon circa 3000 BC, ancient Egypt circa 3150 BC, pre-Hispanic Mexico circa 2000 BC, and Sudan circa 1500 BC.

3.2 Uses

The primary benefit of fermentation is the conversion of sugars and other carbohydrates, e.g., converting juice into wine, grains into beer, carbohydrates into carbon dioxide to leaven bread, and sugars in vegetables into preservative organic acids.

Food fermentation has been said to serve five main purposes:

- Enrichment of the diet through development of a diversity of flavours, aromas, and textures in food substrates
- Preservation of substantial amounts of food through lactic acid, alcohol, acetic acid, and alkaline fermentations
- Biological enrichment of food substrates with protein, essential amino acids, essential fatty acids, and vitamins
- Elimination of antinutrients
- A decrease in cooking time and fuel requirement

3.3 List of Fermented Foods

Fermented foods have played an important role in human health for hundreds of years. Societies known for their long lives have always eaten some form of fermented food. Looking at the list below shows that most of these fermented foods come from Africa, Asia and "old" Europe, all societies that do not suffer from the plague of intestinal problems that beset modern societies.

In general, fermentation increases protein and nutritional levels of food. For example, vitamin B12, folacin and riboflavin were all increased after fermentation of maize flour. Fermented gruels are commonly used as a weaning food for babies in many countries. They reduce bouts of diarrhea significantly when compared with unfermented gruels. This protection lasts even after cooking the gruel. The fermented grains and vegetables are full of the beneficial lactic acid bacteria. This is the family that most probiotics come from. You'll find *Lacotbacillus plantarum* in many of these.

Leuconostoc mesenteroides is one of the most common bacteria found in fermented foods. It plays an important role as it grows rapidly over a wide range of temperatures and pH and so stops bad bacteria getting a foothold. If these foods are heated to a high temperature after fermentation then the beneficial bacteria will be destroyed.

3.4 Fermented foods from round the world

Food	*Ingredient*	*Main species present*	*Country*
Busa	Rice, millet, sugar		Turkey
Beer	Barley	Yeast, lactic acid bacteria	World wide
Cheese	Milk	Lactic acid bacteria, mold	World wide
Chicha	Maize and other grains		South America

Dadih	Milk	Lactic acid bacteria	Indonesia
Dawadawa	Locust beans	Bacillus, Staphylococcus	West Africa
Gari	Cassava	Leuconostoc, Alcaligenes, Corynebacterium, Lactobacillus	Nigeria
Gherkins,salted	Cucumber	Lactic acid bacteria	
Idli/dosa	Rice and black gram	Leuc mesenteroides, Enterococcus faecalis, yeast	India
Injera	Tef	Leuc mesenteroides, P cerevisiae, L plantarum, Sac cerevisiae	Ethiopia
I-sushi	Fish	Lactic acid bacteria, yeast	Japan
Kaanga piro	Maize	Lactic acid bacteria	New Zealand
Kefir	Milk	Streptococcus, Lactobacillus and Leuconostoc sp, Candida kefyr, Kluyveromyces fragilis	Eastern Europe
Kenkey	Maize, sorghum	Lactic acid bacteria	Ghana
Kimchi	Vegetables	Leuc mesenteroides, L brevis, L plantarum	Korea
Koko	Maize, sorghum	Lactic acid bacteria	Ghana
Leavened bread	Wheat	Yeast	Europe, North America
Lambic beer	Barley	Yeasts, lactic acid bacteria	Belgium
Mahewu	Maize	L lactis, Lactobacillus sp	South Africa
Nam	Pork, rice, garlic, salt	P cerevisiae, L plantarum, L brevis	Thailand
Nono	Milk	Lactic acid bacteria	Nigeria
Ogi	Maize, sorghum, millet	L plantarum, Corynebacterium sp, Acetobacter, Yeast	Nigeria
Olives	Olives	Lactic acid bacteria, yeasts	Mediterranean
Palm wine	Palm sap	Yeasts, lactic acid bacteria	World wide
Pin dang	Fish roe	-	Phillipines
Poi	Taro	Lactic acid bacteria	Hawaii

Puto	Rice	Leuc mesenteroides, Enterococcus faecalis	Phillipines
Qula	Yak milk	Lactic acid bacteria, yeast	Tibet
Salami	Meat	Lactic acid bacteria	World wide
Sauerkraut	Cabbage	Lactic acid bacteria	Europe, North America
Sorghum beer	Sorghum	Lactic acid bacteria	South Africa
Sourdough bread	Wheat, rye	Lactic acid bacteria	Europe, North America
Soy sauce, miso	Soy beans	Lactic acid bacteria, mold	South east Asia
Tempeh	Soy beans	Mold, yeast, bacteria	Indonesia
Tibi	Fruit	-	Mexico
Trahanas	Milk and wheat	Lactic acid bacteria	Greece
Yogurt	Milk	Lactic acid bacteria	World wide

3.5 Fermented foods by type

3.5.1 Bean-based

Cheonggukjang, doenjang, miso, natto, soy sauce, stinky tofu, tempeh, soybean paste, Beijing mung bean milk, iru

3.5.2 Grain-based

Amazake, beer, bread, choujiu, gamju, injera, kvass, makgeolli, murri, ogi, sake, sikhye, sourdough, sowans, rice wine, malt whisky, grain whisky, idli, dosa, vodka

3.5.3 Vegetable based

Kimchi, mixed pickle, sauerkraut, Indian pickle, gundruk

3.5.4 Fruit based

Wine, vinegar, cider, perry, brandy, atchara, nata de coco, burong mangga, asinan, pickling, vişinată

3.5.5 Honey based

Mead, metheglin

3.5.6 Dairy based

Cheese, kefir, kumis (mare milk), shubat (camel milk), cultured milk products such as quark, filmjölk, crème fraîche, smetana, skyr, yogurt

3.5.7 Fish based

Bagoong, faseekh, fish sauce, Garum, Hákarl, jeotgal, rakfisk, shrimp paste, surströmming, shidal

3.5.8 Meat based

Jamón ibérico, Chorizo, Salami, pepperoni

3.5.9 Tea based

Kombucha

SELF ASSESSMENT EXERCISES

1. How many of the fermented foods and beverages can you recognize?

2. List the procedure for the production of one food and one beverage.

4.0 CONCLUSION

The primary benefit of fermentation is the conversion of sugars and other carbohydrates, e.g., converting juice into wine, grains into beer, carbohydrates into carbon dioxide to leaven bread, and sugars in vegetables into preservative organic acids.

5.0 SUMMARY

The primary benefit of fermentation is the conversion of sugars and other carbohydrates, e.g., converting juice into wine, grains into beer, carbohydrates into carbon dioxide to leaven bread, and sugars in vegetables into preservative organic acids. Food fermentation has been said to serve five main purposes:

- Enrichment of the diet through development of a diversity of flavours, aromas, and textures in food substrates
- Preservation of substantial amounts of food through lactic acid, alcohol, acetic acid, and alkaline fermentations

- Biological enrichment of food substrates with protein, essential amino acids, essential fatty acids, and vitamins
- Elimination of antinutrients
- A decrease in cooking time and fuel requirement

6.0 TUTOR - MARKED ASSIGNMENTS

1. Find out and document about all the fermented foods and beverages available in Nigeria

2. Analyse the above by:

i. Type of food

ii. State/locality

7.0 REFERENCES

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UNIT 2 Microorganisms used in food and beverage preparation

Content

1.0 introduction

2.0 objectives

3.0 main content

3.1 list of microorganisms used in food and beverage preparation

4.0 conclusion

5.0 summary

6.0 tutor-marked assignments

7.0 references

1.0 INTRODUCTION

Fermented foods are foods produced or preserved by the action of microorganisms. In this context, fermentation typically refers to the fermentation of sugar to alcohol using yeast, but other fermentation processes involve the use of bacteria such as lactobacillus, including the making of foods such as yogurt and sauerkraut. The list below is not exhaustive but would enable you have a wide choice when you want to embark on fermentation.

2.0 OBJECTIVES

At the end of this unit, you should be able to

1. Identify 40 microorganisms used in food and beverage production

2. Categorise the microorganisms into bacteria and fungi

3. Practice fermentation with 2 types of bacteria and 2 types of fungi

3.0 MAIN CONTENT

3.1 List of microorganisms used in food and beverage preparation

Microorganism	Type of Microorganism	Food or Beverage
Acetobacter aceti	bacterium	chocolate
Acetobacter aceti	bacterium	vinegar
Acetobacter fabarum	bacterium	chocolate
Acetobacter fabarum	bacterium	coffee
Acetobacter lovaniensis	bacterium	vegetables
Acetobacter malorum	bacterium	vinegar
Acetobacter orientalis	bacterium	vegetables
Acetobacter pasteurianus	bacterium	chocolate
Acetobacter pasteurianus	bacterium	vinegar
Acetobacter pomorum	bacterium	vinegar
Acetobacter syzygii	bacterium	chocolate
Acetobacter syzygii	bacterium	vinegar
Acetobacter tropicalis	bacterium	chocolate
Acetobacter tropicalis	bacterium	coffee
Arthrobacter arilaitensis	bacterium	smear-ripened cheese
Arthrobacter bergerei	bacterium	smear-ripened cheese
Arthrobacter globiformis	bacterium	smear-ripened cheese
Arthrobacter nicotianae	bacterium	surface-ripened cheese
Arthrobacter nicotianae	bacteria	Tilsit cheese
Arthrobacter variabilis	bacteria	smear-ripened cheese
Aspergillus acidus	fungus	tea
Aspergillus niger	fungus	awamori
Aspergillus fumigatus	fungus	chocolate

Microorganism	Type of Microorganism	Food or Beverage
Aspergillus oryzae	fungus	miso
Aspergillus oryzae	fungus	sake
Aspergillus oryzae	fungus	soy sauce
Aspergillus sojae	fungus	miso
Aspergillus sojae	fungus	soy sauce
Bacillus cereus	bacterium	chocolate
Bacillus coagulans	bacterium	chocolate
Bacillus licheniformis	bacterium	chocolate
Bacillus pumilus	bacterium	chocolate
Bacillus sphaericus	bacterium	stinky tofu
Bacillus stearothermophilus	bacterium	chocolate
Bacillus subtilis	bacterium	chocolate
Bacillus subtilis	bacterium	natto
Bifidobacterium adolescentis	bacterium	yogurt
Bifidobacterium animalis	bacterium	dairy
Bifidobacterium bifidum	bacterium	dairy
Bifidobacterium breve	bacterium	dairy
Bifidobacterium breve	bacterium	soy
Bifidobacterium infantis	bacterium	dairy
Bifidobacterium lactis	bacterium	dairy
Bifidobacterium longum	bacterium	dairy
Bifidobacterium pseudolongum	bacterium	dairy
Bifidobacterium thermophilum	bacterium	dairy
Brachybacterium alimentarium	bacterium	Beaufort cheese
Brachybacterium alimentarium	bacterium	Gruyère cheese
Brachybacterium tyrofermentans	bacterium	Beaufort cheese
Brachybacterium tyrofermentans	bacterium	Gruyère cheese
Brevibacterium aurantiacum	bacterium	cheese
Brevibacterium casei	bacterium	smear-ripened cheese

Microorganism	Type of Microorganism	Food or Beverage
Brevibacterium linens	bacterium	smear-ripened cheese
Candida colliculosa	fungus	cheese
Candida colliculosa	fungus	kefir
Candida exiguus	fungus	sourdough bread
Candida humicola	fungus	chocolate
Candida kefyr	fungus	surface-ripened cheese
Candida krusei	fungus	surface-ripened cheese
Candida milleri	fungus	sourdough bread
Candida mycoderma	fungus	Limburger cheese
Candida pelliculosa	fungus	chocolate
Candida rugosa	fungus	chocolate
Candida tropicalis	fungus	chocolate
Candida utilis	fungus	cheese
Candida valida	fungus	sourdough
Candida vini	fungus	Reblochon cheese
Candida zeylanoides	fungus	Reblochon cheese
Carnobacterium divergens	bacterium	cheese
Carnobacterium divergens	bacterium	fish
Carnobacterium divergens	bacterium	meat
Carnobacterium maltaromaticum	bacterium	dairy
Carnobacterium piscicola	bacterium	meat
Corynebacterium ammoniagenes	bacterium	cheese
Corynebacterium casei	bacterium	smear-ripened cheese
Corynebacterium flavescens	bacterium	cheese
Corynebacterium mooreparkense	bacterium	smear-ripened cheese
Corynebacterium variabile	bacterium	cheese
Cyberlindnera mrakii	fungus	wine
Cystofilobasidium infirmominiatum	fungus	cheese
Debaryomyces hansenii	fungus	smear-ripened cheese

Microorganism	Type of Microorganism	Food or Beverage
Debaryomyces hansenii	fungus	Reblochon cheese
Debaryomyces kloeckeri	fungus	Limburger cheese
Dekkera bruxellensis	fungus	beer
Enterococcus durans	bacterium	dairy
Enterococcus faecalis	bacterium	butter
Enterococcus faecalis	bacterium	cheese
Enterococcus faecalis	bacterium	cream
Enterococcus faecalis	bacterium	ham
Enterococcus faecalis	bacterium	miso
Enterococcus faecalis	bacterium	pickle
Enterococcus faecalis	bacterium	sausage
Enterococcus faecalis	bacterium	soy sauce
Enterococcus faecium	bacterium	Manchego cheese
Enterococcus faecium	bacterium	ham
Enterococcus faecium	bacterium	miso
Enterococcus faecium	bacterium	pickle
Enterococcus faecium	bacterium	soy sauce
Fusarium domesticum	fungus	cheese
Geotrichum candidum	fungus	cheese
Gluconacetobacter azotocaptans	bacterium	chocolate
Gluconacetobacter azotocaptans	bacterium	coffee
Gluconacetobacter diazotrophicus	bacterium	chocolate
Gluconacetobacter diazotrophicus	bacterium	coffee
Gluconacetobacter entanii	bacterium	vinegar
Gluconacetobacter europaeus	bacterium	vinegar
Gluconacetobacter hansenii	bacterium	vinegar
Gluconacetobacter johannae	bacterium	chocolate
Gluconacetobacter johannae	bacterium	coffee
Gluconacetobacter oboediens	bacterium	vinegar

Microorganism	Type of Microorganism	Food or Beverage
Gluconacetobacter xylinus	bacterium	vinegar
Gluconobacter oxydans	bacterium	chocolate
Hafnia alvei	bacterium	cheese
Halomonas elongata	bacterium	meat
Issatchenkia orientalis	fungus	kefir
Kazachstania exigua	fungus	kefir
Kazachstania unispora	fungus	kefir
Kloeckera africana	fungus	chocolate
Kloeckera apis	fungus	chocolate
Kloeckera javanica	fungus	chocolate
Kluyveromyces lactis	fungus	cheese
Kluyveromyces marxianus	fungus	cheese
Kluyveromyces marxianus	fungus	chocolate
Kocuria rhizophila	bacterium	cheese
Kocuria rhizophila	bacterium	meat
Kocuria varians	bacterium	dairy
Kocuria varians	bacterium	sausage
Lactobacillus acetotolerans	bacterium	fruit
Lactobacillus acetotolerans	bacterium	vegetables
Lactobacillus acidifarinae	bacterium	sourdough bread
Lactobacillus acidipiscis	bacterium	dairy
Lactobacillus acidipiscis	bacterium	fish
Lactobacillus acidophilus	bacterium	vegetables
Lactobacillus acidophilus	bacterium	yogurt
Lactobacillus alimentarius	bacterium	fish
Lactobacillus alimentarius	bacterium	meat
Lactobacillus brevis	bacterium	Canestrato Pugliese cheese
Lactobacillus brevis	bacterium	vegetables
Lactobacillus brevis ssp. *linens*	bacterium	kefir

Microorganism	Type of Microorganism	Food or Beverage
Lactobacillus bucheri	bacterium	bread
Lactobacillus bucheri	bacterium	wine
Lactobacillus cacaonum	bacterium	chocolate
Lactobacillus casei	bacterium	Idiazabal cheese
Lactobacillus casei	bacterium	Manchego cheese
Lactobacillus casei	bacterium	Roncal cheese
Lactobacillus casei	bacterium	yogurt
Lactobacillus casei ssp. *pseudoplantarum*	bacterium	Grana Padano cheese
Lactobacillus casei ssp. *pseudoplantarum*	bacterium	Parmigiano-Reggiano cheese
Lactobacillus cellobiosus	bacterium	chocolate
Lactobacillus collinoides	bacterium	cider
Lactobacillus composti	bacterium	*shōchū*
Lactobacillus coryniformis	bacterium	cheese
Lactobacillus crispatus	bacterium	sourdough bread
Lactobacillus curvatus	bacterium	Cacio di Fossa cheese
Lactobacillus curvatus	bacterium	Canestrato Pugliese cheese
Lactobacillus curvatus	bacterium	Pecorino Romano cheese
Lactobacillus curvatus	bacterium	Pecorino Sardo cheese
Lactobacillus curvatus	bacterium	sausage
Lactobacillus delbrueckii	bacterium	vegetables
Lactobacillus delbrueckii ssp. *bulgaricus*	bacterium	cheese
Lactobacillus delbrueckii ssp. *bulgaricus*	bacterium	yogurt
Lactobacillus delbrueckii ssp. *lactis*	bacterium	Pecorino Romano cheese
Lactobacillus dextrinicus	bacterium	meat
Lactobacillus diolivorans	bacterium	chicha
Lactobacillus fabifermentans	bacterium	chocolate
Lactobacillus farciminis	bacterium	fish

Microorganism	Type of Microorganism	Food or Beverage
Lactobacillus farciminis	bacterium	soy
Lactobacillus fermentum	bacterium	chocolate
Lactobacillus fermentum	bacterium	Pecorino Romano cheese
Lactobacillus fermentum	bacterium	sourdough bread
Lactobacillus fructivorans	bacterium	
Lactobacillus frumeti	bacterium	
Lactobacillus gasseri	bacterium	dairy
Lactobacillus gasseri	bacterium	sourdough bread
Lactobacillus ghanensis	bacterium	chocolate
Lactobacillus hammesii	bacterium	sourdough bread
Lactobacillus harbinensis	bacterium	vegetables
Lactobacillus helveticus	bacterium	cheese
Lactobacillus helveticus	bacterium	vegetables
Lactobacillus hilgardii	bacterium	chocolate
Lactobacillus hilgardii	bacterium	wine
Lactobacillus homohiochii	bacterium	sake
Lactobacillus homohiochii	bacterium	sourdough bread
Lactobacillus hordei	bacterium	
Lactobacillus jensenii	bacterium	bread
Lactobacillus johnsonii	bacterium	dairy
Lactobacillus johnsonii	bacterium	sourdough bread
Lactobacillus kefiranofaciens	bacterium	kefir
Lactobacillus kefiri	bacterium	kefir
Lactobacillus kimchii	bacterium	kimchi
Lactobacillus kisonensis	bacterium	pickle
Lactobacillus kunkeei	bacterium	wine
Lactobacillus mali	bacterium	cider
Lactobacillus mali	bacterium	rum
Lactobacillus mali	bacterium	wine

Microorganism	Type of Microorganism	Food or Beverage
Lactobacillus manihotivorans	bacterium	cassava
Lactobacillus mindensis	bacterium	sourdough bread
Lactobacillus mucosae	bacterium	sourdough bread
Lactobacillus nagelii	bacterium	wine
Lactobacillus namuresis	bacterium	sourdough bread
Lactobacillus nantesis	bacterium	sourdough bread
Lactobacillus nodensis	bacterium	dairy
Lactobacillus oeni	bacterium	wine
Lactobacillus otakiensis	bacterium	pickle
Lactobacillus panis	bacterium	sourdough bread
Lactobacillus parabrevis	bacterium	cheese
Lactobacillus parabrevis	bacterium	kefir
Lactobacillus parabrevis	bacterium	vegetables
Lactobacillus parabuchneri	bacterium	sourdough bread
Lactobacillus paracasei	bacterium	dairy
Lactobacillus paracasei	bacterium	meat
Lactobacillus paracasei ssp. *paracasei*	bacterium	Cacio di Fossa cheese
Lactobacillus paracasei ssp. *paracasei*	bacterium	Canestrato Pugliese cheese
Lactobacillus paracasei ssp. *paracasei*	bacterium	Pecorino Sardo cheese
Lactobacillus parakefiri	bacterium	kefir
Lactobacillus paralimentarius	bacterium	sourdough bread
Lactobacillus paraplatarum	bacterium	cheese
Lactobacillus paraplatarum	bacterium	vegetables
Lactobacillus pentosus	bacterium	Canestrato Pugliese cheese
Lactobacillus pentosus	bacterium	fish
Lactobacillus pentosus	bacterium	fruit
Lactobacillus pentosus	bacterium	wine
Lactobacillus perolens	bacterium	cheese

Microorganism	Type of Microorganism	Food or Beverage
Lactobacillus perolens	bacterium	vegetables
Lactobacillus plantarum	bacterium	Cacio di Fossa cheese
Lactobacillus plantarum	bacterium	Canestrato Pugliese cheese
Lactobacillus plantarum	bacterium	chocolate
Lactobacillus plantarum	bacterium	Idiazabal cheese
Lactobacillus plantarum	bacterium	Manchego cheese
Lactobacillus plantarum	bacterium	Pecorino Romano cheese
Lactobacillus plantarum	bacterium	Roncal cheese
Lactobacillus plantarum	bacterium	sausage
Lactobacillus plantarum	bacterium	vegetables
Lactobacillus pobuzihii	bacterium	fruit
Lactobacillus pontis	bacterium	sourdough bread
Lactobacillus rapi	bacterium	pickle
Lactobacillus rapi	bacterium	vegetables
Lactobacillus reuteri	bacterium	sourdough bread
Lactobacillus rhamnosus	bacterium	Grana Padano cheese
Lactobacillus rhamnosus	bacterium	Parmigiano-Reggiano cheese
Lactobacillus rhamnosus	bacterium	meat
Lactobacillus rhamnosus	bacterium	vegetables
Lactobacillus rossiae	bacterium	sourdough bread
Lactobacillus sakei	bacterium	sake
Lactobacillus sakei	bacterium	sausage
Lactobacillus salivarius	bacterium	dairy
Lactobacillus sanfranciscensis	bacterium	sourdough bread
Lactobacillus satsumensis	bacterium	*shōchū*
Lactobacillus secaliphilus	bacterium	sourdough bread
Lactobacillus senmaizukei	bacterium	pickles
Lactobacillus siliginis	bacterium	sourdough bread

Microorganism	Type of Microorganism	Food or Beverage
Lactobacillus similis	bacterium	rum
Lactobacillus spicheri	bacterium	sourdough bread
Lactobacillus suebicus	bacterium	fruit
Lactobacillus spp.	bacterium	butter
Lactobacillus spp.	bacterium	olive
Lactobacillus sunkii	bacterium	pickle
Lactobacillus tucceti	bacterium	dairy
Lactobacillus tucceti	bacterium	sausage
Lactobacillus vaccinostercus	bacterium	fruit
Lactobacillus vaccinostercus	bacterium	vegetables
Lactobacillus versmoldesis	bacterium	sausage
Lactobacillus yamanashiensis	bacterium	cider
Lactobacillus yamanashiensis	bacterium	wine
Lactococcus lactis	bacterium	buttermilk
Lactococcus lactis	bacterium	chocolate
Lactococcus lactis ssp. *cremoris*	bacterium	Cheddar cheese
Lactococcus lactis ssp. *lactis*	bacterium	cheese
Lactococcus raffinolactis	bacterium	cheese
Lactococcus spp.	bacterium	butter
Lecanicillium lecanii	fungus	cheese
Leuconostoc carnosum	bacterium	meat
Leuconostoc citreum	bacterium	cheese
Leuconostoc citreum	bacterium	fish
Leuconostoc fallax	bacterium	sauerkraut
Leuconostoc holzapfelii	bacterium	coffee
Leuconostoc inhae	bacterium	kimchi
Leuconostoc kimchii	bacterium	kimchi
Leuconostoc lactis	bacterium	cheese
Leuconostoc mesenteroides	bacterium	chocolate

Microorganism	Type of Microorganism	Food or Beverage
Leuconostoc mesenteroides	bacterium	vegetables
Leuconostoc mesenteroides ssp. *cremoris*	bacterium	cheese
Leuconostoc mesenteroides ssp. *cremoris*	bacterium	vegetables
Leuconostoc mesenteroides ssp. *dextranicum*	bacterium	butter
Leuconostoc mesenteroides ssp. *dextranicum*	bacterium	Idiazabal cheese
Leuconostoc mesenteroides ssp. *dextranicum*	bacterium	pickle
Leuconostoc mesenteroides ssp. *dextranicum*	bacterium	Roncal cheese
Leuconostoc mesenteroides ssp. *mesenteroides*	bacterium	Idiazabal cheese
Leuconostoc mesenteroides ssp. *mesenteroides*	bacterium	Roncal cheese
Leuconostoc palmae	bacterium	palm wine
Leuconostoc pseudomesenteroides	bacterium	butter
Leuconostoc pseudomesenteroides	bacterium	buttermilk
Leuconostoc pseudomesenteroides	bacterium	sour cream
Leuconostoc spp.	bacterium	butter
Leuconostoc spp.	bacterium	olive
Leuconostoc spp.	bacterium	wine
Macrococcus caseolyticus	bacterium	cheese
Macrococcus caseolyticus	bacterium	sausage
Microbacterium foliorum	bacterium	surface-ripened cheese
Microbacterium gubbeenense	bacteria	Limburger cheese
Microbacterium gubbeenense	bacterium	smear-ripened cheese
Microbacterium gubbeenense	bacteria	Tilsit cheese
Micrococcus luteus	bacterium	cheese
Micrococcus lylae	bacterium	sausage
Mucor hiemalis	fungus	soy bean curd
Mucor plumbeus	fungus	cheese
Mucor racemosus	fungus	cheese
Mucor racemosus	fungus	chocolate

Microorganism	Type of Microorganism	Food or Beverage
Oenococcus oeni	bacterium	wine
Pediococcus acidilactici	bacterium	sausage
Pediococcus acidilactici	bacterium	vegetables
Pediococcus pentosaceus	bacterium	sausage
Penicillium album	fungus	farmhouse cheeses
Penicillium camemberti	fungus	cheese
Penicillium caseifulvum	fungus	cheese
Penicillium chrysogenum	fungus	cheese
Penicillium chrysogenum	fungus	sausage
Penicillium commune	fungus	surface-ripened cheese
Penicillium nalgiovense	fungus	cheese
Penicillium nalgiovense	fungus	ham
Penicillium nalgiovense	fungus	sausage
Penicillium roqueforti	fungus	cheese
Penicillium solitum	fungus	meat
Pichia fermentans	fungus	dairy
Pichia fermentans	fungus	kefir
Pichia fermentans	fungus	wine
Propionibacterium acidipropionici	bacterium	cheese
Propionibacterium freudenreichii ssp. *freudenreichii*	bacterium	dairy
Propionibacterium freudenreichii ssp. *shermanii*	bacterium	Emmental cheese
Propionibacterium jensenii	bacterium	cheese
Propionibacterium thoenii	bacterium	cheese
Proteus vulgaris	bacterium	surface-ripened cheese
Pseudomonas fluorescens	bacterium	yogurt
Psychrobacter celer	bacterium	cheese
Rhizopus microsporus ssp. *oligosporus*	fungus	oncom
Rhizopus microsporus ssp. *oligosporus*	fungus	tempeh

Microorganism	Type of Microorganism	Food or Beverage
Rhodosporidium infirmominiatum	fungus	cheese
Rhodotorula glutinis	fungus	chocolate
Rhodotorula minuta	fungus	smear-ripened cheese
Rhodotorula rubra	fungus	chocolate
Saccharomyces bayanus	fungus	beer
Saccharomyces bayanus	fungus	cider
Saccharomyces bayanus	fungus	wine
Saccharomyces carlsbergensis	fungus	lager beer
Saccharomyces cerevisiae	fungus	ale beer
Saccharomyces cerevisiae	fungus	bread
Saccharomyces cerevisiae	fungus	cider
Saccharomyces cerevisiae	fungus	cheese
Saccharomyces cerevisiae	fungus	chocolate
Saccharomyces cerevisiae	fungus	wine
Saccharomyces pastorianus	fungus	lager beer
Saccharomyces rouzii	fungus	miso
Saccharomyces uvarum	fungus	lager beer
Staphylococcus carnosus	bacterium	cheese
Staphylococcus carnosus ssp. *carnosus*	bacterium	sausage
Staphylococcus condimenti	bacterium	soy
Staphylococcus equorum	bacterium	meat
Staphylococcus equorum ssp. *linens*	bacterium	cheese
Staphylococcus fleurettii	bacterium	cheese
Staphylococcus piscifermentans	bacterium	fish
Staphylococcus saphrophyticus	bacterium	Harzer cheese
Staphylococcus sciuri ssp. *carnaticus*	bacterium	cheese
Staphylococcus simulans	bacterium	sausage
Staphylococcus succinus	bacterium	dairy
Staphylococcus succinus	bacterium	meat

Microorganism	Type of Microorganism	Food or Beverage
Staphylococcus vitulinus	bacterium	cheese
Staphylococcus vitulinus	bacterium	meat
Staphylococcus warneri	bacterium	meat
Staphylococcus xylosus	bacterium	cheese
Staphylococcus xylosus	bacterium	sausage
Streptococcus gallolyticus	bacterium	dairy
Streptococcus salivarius	bacterium	yogurt
Streptococcus thermophilus	bacterium	cheese
Streptococcus thermophilus	bacterium	yogurt
Streptomyces griseus	bacterium	meat
Tetragenococcus halophilus	bacterium	miso
Tetragenococcus halophilus	bacterium	soy sauce
Tetragenococcus koreensis	bacterium	kimchi
Torulaspora delbrueckii	fungus	smear-ripened cheese
Torulopsis versatilis	fungus	miso
Thrichosporon beigelii	fungus	smear-ripened cheese
Verticillium lecanii	fungus	Tomme cheese
Weissella beninensis	bacterium	cassava
Weissella cibaria	bacterium	kimchi
Weissella fabaria	bacterium	chocolate
Weissella ghanesis	bacterium	chocolate
Weissella koreensis	bacterium	kimchi
Weissella paramesenteroides	bacterium	sausage
Weissella thailandesis	bacterium	fish
Yarrowia lipolytica	fungus	Raclette cheese
Yarrowia lipolytica	fungus	smear-ripened cheese
Yarrowia lipolytica	fungus	dairy
Zygotorulaspora florentina	fungus	kefir
Zymomonas mobilis	bacterium	palm wine

Microorganism	Type of Microorganism	Food or Beverage
Zymomonas mobilis	bacterium	pulque

SELF –ASSESSMENT EXERCISES

Visit a microbiology shop and find out the available types of microorganisms used in food and beverage preparation

4.0 CONCLUSION

To make very successful fermented food and beverage, it is important you make the right choices of microorganisms.

5.0 SUMMARY

There are countless microorganisms available for use in the fermentation of food and beverages.

6.0 TUTOR-MARKED ASSIGNMENTS

Choose 2 types of bacteria and 2 types of fungi and for each of them, ferment a food and a beverage

7.0 REFERENCES

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UNIT 3 FERMENTED FOODS

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1.0 INTRODUCTION

Fermented foods are foods produced or preserved by the action of microorganisms. In this context, fermentation typically refers to the fermentation of sugar to alcohol using yeast, but other fermentation processes involve the use of bacteria such as lactobacillus, including the making of foods such as yogurt and sauerkraut.

2.0 OBJECTIVES

At the end of this unit you should be able to

1. Explain the fermentation process
2. Classify starter cultures
3. Analyse the cultures used for milk, vegetables, fruits, meat and grain fermentation.
4. Make at least 2 fermented products.

3.0 MAIN CONTENT

3.1 Fermentation processes

Fermentations can basically be performed either by spontaneous fermentation, by backslopping, or by addition of starter cultures. By spontaneous fermentation the raw material, and its initial treatment, will encourage the growth of an indigenous flora. For most spontaneous fermentations, a microbial succession takes place: quite often LAB will initially dominate, followed by various species of yeasts. Moulds will only grow aerobically, which limits their occurrence in certain types of fermented products. LAB produce lactic acid and other antimicrobial substances that will inhibit the growth of harmful bacteria, along with reducing the sugar content, thereby prolonging the shelf life of the product.

Yeasts mostly produce aroma components and alcohols. When moulds are involved in fermentation, they generally contribute by producing both intra- and extracellular proteolytic and lipolytic enzymes that highly influence the flavour and texture of the product. In back-slopping, a part of a previous batch of a fermented product is used to inoculate the new batch. This procedure produces a higher initial number of beneficial microorganisms than found in raw material and ensures a faster and more reliable fermentation than occurs in spontaneous fermentation. This procedure probably also favors the growth of bacteria producing antimicrobial substances, ensuring the growth of the same bacteria every time. Examples of back-slopping are home-made fermentation of milk, vegetables, and cereals. Bread production made with sourdough is often also done by back-slopping; a sample of the previous days' sourdough is used to inoculate a new batch of dough.

Addition of starter cultures is most often used when it is possible to inactivate the indigenous flora by heat treatment of the raw material, permitting the growth of only the added starter microorganisms. However, it is not always possible to heat-treat the raw material (e.g., fruits and vegetables) without influencing the texture of the final product.
Nevertheless, the addition of starter cultures—especially those containing a bacteriocinproducingstrain alone or in combination with selected bacteriocin-resistant strains—may in fermentations of plants yield a greater possibility that the desirable flora will dominate in the fermentation.

3.2 Starter cultures

Starter cultures can basically be classified as; single strain starter and multiple strain starter.

Single-strain starter cultures are primarily used for yeasts and moulds in the production of beer and wine, and LAB for the production of a few dairy products, sausages, and sauerkraut.

Multiple starter cultures are used for dairy products, sourdough, sausages, and wine. Mixed undefined bacterial starter cultures, also called traditional or artisanal starters are primarily used in the dairy industry and in sourdough production.

3.2.1 Bacterial starter cultures

Starter cultures can also be classified according to their optimal growth temperature. The most important bacteria for food fermentation are designated lactic acid bacteria (LAB). They are gram-positive rods or cocci, non–spore formers, catalase negative, obligatory fermentative, microaerophilic, usually nonmotile bacteria having extensive growth requirements. They produce mainly lactic acid from glucose fermentation. The first classification of LAB was made in 1919 by S. Orla-Jensen. However,utilization of DNA technology and molecular typing methods has had a great impact on the taxonomy of bacteria and has led to a great deal of taxonomic revision. Homofermentative LAB mainly makes lactic acid as their final product, whereas heterofermentative LAB make equal amounts of lactic acid, acetic acid, and CO2. Other bacteria such as Acetobacter, Bifidobacterium, Micrococcus,and Staphylococcus are also used as starter cultures for food and beverage fermentations; Brevibacterium and Propionibacterium are used as secondary or adjunct cultures. Some Lactobacillus species are also used as adjunct cultures.

3.2.2 Cultures for Milk Fermentation

The utilization of starter cultures in industrial milk fermentation is widespread. The most important starter cultures are the LAB. These cultures often consist only of mesophilic or thermophilic LAB; however, mixtures can also occur. Mesophilic starter cultures originate from north and east Europe. They consist primarily of Lactococcus lactis subsp. Cremoris (L. cremoris), Lactococcus lactis subsp. lactis (L. lactis), Lactococcus lactis subsp. Lactis biovar. diacetylactis (L. diacetylactis), Leuconostoc mesenteroides subsp. cremoris, and Leuconostoc lactis. Especially, L. cremoris and L. cremoris are capable of rapid acidification of milk. L. diacetylactis, Leuconostoc mesenteroides subsp. cremoris, and Leuconostoclactis can catabolize citrate into CO2 and diacetyl. CO2 is responsible for the production of holes in the cheeses, and diacetyl, the characteristic flavour of butter, is important for the flavour of many cheeses and fermented milk products. The diacetyl producing organisms are often called the aroma producers or L. lactis subsp. lactis (citrate +). Lactobacillus paracasei and Lactobacillus casei are the most common mesophilic lactobacilli found in many cheeses and are in some cases used as adjunct cultures.

Lactobacillus rhamnosus, Lactobacillus plantarum, and Lactobacillus curvatus are also found in many cheeses . The dairy propionibacteria Propionibacterium shermanii and Propionibacterium freudenreichii are used in some Swiss-type cheeses such as Emmental, Gruye` re, and Comte´, in which they slowly catabolize lactate to propionate, acetate, and CO2. This is important for the production of holes and taste of the cheeses. Micrococcacaceae and Brevibacterium are used as surface flora in various cheeses ; they are important for cheese ripening.

Different types of mixed starter cultures have been developed. The composition of the different mesophilic starter cultures, most abundant cheese produced is Cheddar cheese. It is commonly produced by the use of a multiple strain starter culture of Lactococcus lactis subsp. cremoris and Lactococcus lactis subsp. lactis, with or without Streptococcus thermophilus.

However, a mixed O-culture, TK5, has also been developed . Thermophilic cultures originate from south and east Europe. They consist mainly of Streptococcus thermophilus, Lactobacillus delbrueckii subsp. bulgaricus and lactis, and Lactobacillus helveticus. The thermophilic LAB are used for rapid acidification or as adjuncts in cheeses. Streptococcus thermophilus, Lactobacillus delbrueckii subsp. bulgaricus, and some Lactobacillus delbrueckii subsp. lactis catabolize lactose into lactate and galactose, which are secreted. The residual galactose can create problems (e.g., growth of undesirable bacteria) in cheese and influences the browning of pizza cheese. Lactobacillus helveticus can use galactose as a carbon source and thereby remove the residual galactose. Furthermore, some strains of Lactobacillus helveticus are very proteolytic, thereby influencing the taste and texture of cheese. Thermophilic LAB can also produce acetaldehyde, which is the characteristic flavour of yogurt. The composition of these starter cultures varies. Both
defined single or multiple starter strain cultures and mixed undefined cultures are used. Mozzarella and yogurt are commonly produced by single or multiple strain starters that contain one or more S. thermophilus and Lactobacillus delbrueckii subsp. bulgaricus strains, but many cooked cheeses are produced with mixed cultures. They are used either as milk cultures or whey cultures, with or without rennet. Thermophilic cultures and some examples of their products.

Other cheeses or fermented milk products are made with both mesophilic or thermophilic LAB starter cultures, or by addition of other LAB such as Enterococcus faecium,Lactobacillus acidophilus, or other genera of bacteria (e.g., Bifidobacterium). Yeast and mould can also be added.

One of the disadvantages of using pure bacterial starter cultures is that they are more sensitive to bacteriophages than undefined mixed starters or indigenous flora, where there will always be strains present that can survive phage attack and continue fermentation.
Lactic acid fermentations of milk for cheese production are especially susceptible to phages, and special precautions have to be taken in order to exclude them. The use of phage-resistant starter cultures, a high level of cleaning and sanitation, use of closed vats equipped with filters, specially designed pipelines, equipment and facilities, minimal access of persons, and high personal hygiene are all recommended to achieve this. In this way, it was possible to use a mixed O-culture, TK5, for production of Cheddar cheese in Denmark for 11 years before bacteriophages able to inhibit acidification appeared. Unfortunately, the phages became so virulent that after 12 years of production, it was not possible to use the TK5 starter culture any longer in the dairy.

3.2.3 Cultures for Fermentation of Vegetables, Fruits, and Grains

Plant fermentations involve either lactic acid, acetic acid, or alcoholic fermentation or a combination of these fermentation types. In alcoholic fermentation, it is mainly yeast (Saccharomyces cerevisiae) and fungi (Aspergillus oryzae) that participate; however, lactobacilli and Pediococcus can also be involved. Acetic acid fermentation, used for production of vinegar, is a two-stage fermentation process in which the first stage includes an alcoholic fermentation followed by the oxidization of ethanol via acetaldehyde to acetic acid . The typical raw materials are grapes, potatoes, or rice. Different subspecies of Acetobacter (A. acati, A. pasteurianus, and A. hansenii) and Gluconobacter oxydans are used for vinegar production. Pure cultures are not widely employed in the acetic acid fermentation industry Traditional fermentations of vegetables, fruits, and grains most often include a lactic acid fermentation involving many different species of LAB that are active at different stages of the fermentation process; this is followed by fermentation by yeast and mould

Lactobacillus plantarum and Leuconostoc mesenteroides are the major microorganisms; however, many other LAB (e.g., Lactobacillus species and Pediococcus) may be involved.
Fermentation of vegetables is difficult to control because it depends on the quality of the raw material, the harvesting condition, and the temperature, which are vital in providing the optimal conditions for growth of the desirable microorganisms. The addition of salt, either as dry salt (2–3% w/v) or in solution (4–10% w/v) (called brining) and the creation of an anaerobic condition is commonly the initial step in fermentation of vegetables. One obstacle is that raw vegetables cannot normally be pasteurized without adverse effects on the product texture. Another issue is that vegetable fermentation often relies on a very complex process in which many different bacteria succeed each other in very specific ways.

Many different plant fermentations are commercially produced and most often on a small scale. Currently only olives, pickled cucumbers, sauerkraut, and kimchi areindustrially produced in economically important large amounts. Commonly, the fermentations are performed by spontaneous fermentation or back-slopping. In a few cases,utilization of LAB as single-strain cultures has been tried successfully. For production of sauerkraut, Lactobacillus plantarum , Lactobacillus curvatus , and Leuconostoc mesenteries alone or combined with Lactococcus lactis have been tried. Lactobacillus plantarum and Lactobacillus pentosus have been used in olive fermentation; Lactobacillus plantarum, Lactobacillus pentosus , and Pediococcus pentosaceus successfully for pickled cucumbers.
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Different grains [e.g., maize, rice, sorghum and legumes soybeans,lupins, peas, lentils can be fermented, and most do not involve addition of starter cultures but are fermented by spontaneous fermentation or back-slopping. However, starter cultures are used for production of sourdough from wheat or rye. They are used as either single- or multiple-strains starters, with or without the addition of yeast. However, back-slopping using a batch of dough derived from a previous fermentation to inoculate the next batch of dough is still a common practice in industrial production in Denmark, Finland, and Germany. Another way to start the fermentation is by addition of dried dough. Many different LAB (especially Lactobacillus species) have been isolated from sour dough.

3.2.4 Cultures for Meat Fermentation

Starter cultures for meat fermentation are mainly used in the production of fermented sausages. These cultures are either single- or multiple-strain cultures of LAB and/or staphylococci. However, sausages may also be produced without the addition of starter cultures, relying instead on the indigenous microflora in the meat. However, starter cultures provide technological advantages such as rapid and uniform acidification, good texture and slice-ability, production of desirable flavour compounds, enhanced safety, good colour formation and stability, and better control over the fermentation process. Staphylococci are important for the aroma and colour formation and stability; LAB is central for the other properties. Because meat contains extremely low amounts of sugar, the addition of carbohydrate influences the final pH. There are two main types of sausages, the northern European type in which the sausages are smoked and dried, and the southern European sausages that are dried with or without mould present. Generally the sausages from southern Europe are drier than the sausages from northern Europe (semi-dry). Most fermentations are carried out at 17–24jC, although variations occur. For example, U.S. pepperoni sausages are fermented at 40jC.

3.2.5 Yeasts used as starter cultures

Yeasts are involved in both spontaneous and controlled fermentations. For spontaneous fermentation processes, the yeasts are introduced by either the raw materials or via the process equipment. When yeasts are used as starter cultures, they are in general used as single cultures and may be introduced either to initiate the fermentation process or at a later stage in the fermentation to ensure optimal aroma production. Most yeast species are able to grow under both aerobic and anaerobic conditions. However, some yeast species are specifically respiratory yeasts whereas others are fermentative yeasts for which respiration is repressed even at aerobic conditions. Primarily, yeasts utilize carbohydrates as carbon sources, which are converted into alcohols and CO2 as well as a number of secondary metabolites such as esters, organic acids, aldehydes, and ketones.

Yeasts involved in the fermentation of foods and beverages belong primarily to the ascomycetous yeasts. Among these, the most well described yeast species is undoubtedly Saccharomyces cerevisiae. This species is used worldwide for the production of bread, wine, beer, cheese and so forth and is overall the predominant yeast starter culture in use.
Other important yeast species are Saccharomyces pastorianus, used for production of lager beer, and Debaryomyces hansenii, used for production of cheese and fermented meat products. Yeast species other than the above mentioned are potential starter cultures and do often occur in high numbers during spontaneous fermentations. The evolvements of DNA technologies and molecular typing techniques have over the recent decades influenced significantly the taxonomic position of many yeast genera and further reorganizations are expected in the future. For a current taxonomic description of yeast species, the taxonomic keys of Kurtzman and Fell and Barnett et al. should be consulted.

The benefits obtained by moving from spontaneous fermentations to controlled fermentations are many and, therefore, there seems to be a growing interest in the use of yeasts as purified starter cultures, not only in the control of existing fermentation processes but also in the development of new food products. In controlled fermentation, the habitat of the yeast species as well as the various functions of different yeast species should be taken into consideration as well as any probiotic property or possible pathogenic hazard. Also, the taxonomic position of the starter cultures must be clarified and methods for typing at subspecies level introduced.

3.3 Production of yoghurt

Yogurt or yoghurt is a dairy product produced by bacterialfermentation of milk. The bacteria used to make yogurt are known as "yogurt cultures". Fermentation of lactose by these bacteria produces lactic acid, which acts on milk protein to give yogurt its texture and its characteristic tang.

Worldwide, cow's milk is most commonly used to make yogurt, but milk from water buffalo, goats, ewes, mares, camels, and yaks is also used in various parts of the world.

Dairy yogurt is produced using a culture of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus salivarius* subsp. *thermophilus* bacteria. In addition, other lactobacilli and bifidobacteria are also sometimes added during or after culturing yogurt.

By food law, some countries require a certain amount of colony forming units of microorganisms to allow sour milk be named as "yogurt", e.g., Swiss Food Law: Article 56 yogurt 2 The final product must contain a total of at least 10 million colony forming units of microorganisms under paragraph 1 or 1.2 per gram.

The milk is first heated to about 80 °C (176 °F) to kill any undesirable bacteria and to denature the milk proteins so that they set together rather than form curds. The milk is then cooled to about 45 °C (112 °F). The bacteria culture is added, and the temperature is maintained for 4 to 7 hours to allow fermentation.

3.4 Production of cheese

Cheese is a generic term for a diverse group of milk-based food products. Cheese is produced in wide-ranging flavours, textures, and forms.

Cheese consists of proteins and fat from milk, usually the milk of cows, buffalo, goats, or sheep. It is produced by coagulation of the milk protein casein. Typically, the milk is acidified and addition of the enzyme rennet causes coagulation. The solids are separated and pressed into final form. Some cheeses have molds on the rind or throughout. Most cheeses melt at cooking temperature.

Hundreds of types of cheese are produced. Their styles, textures and flavours depend on the origin of the milk (including the animal's diet), whether they have been pasteurized, the butterfat content, the bacteria and mold, the processing, and aging. Herbs, spices, or wood smoke may be used as flavouring agents. The yellow to red colour of many cheeses, such as Red Leicester, is formed from adding annatto.

For a few cheeses, the milk is curdled by adding acids such as vinegar or lemon juice. Most cheeses are acidified to a lesser degree by bacteria, which turn milk sugars into lactic acid, then the addition of rennet completes the curdling. Vegetarian alternatives to rennet are available; most are produced by fermentation of the fungus*Mucor miehei*, but others have been extracted from various species of the *Cynara* thistle family.

Cheese is valued for its portability, long life, and high content of fat, protein, calcium, and phosphorus. Cheese is more compact and has a longer shelf life than milk, although how long a cheese will keep may depend on the type of cheese; labels on packets of cheese often claim that a cheese should be consumed within three to five days of opening. Generally speaking, hard cheeses last longer than soft cheeses, such as Brie or goat's milk cheese. Cheese makers near a dairy region may benefit from fresher, lower-priced milk, and lower shipping costs. The long storage life of some cheese, especially if it is encased in a protective rind, allows selling when markets are favorable. Additional ingredients may be added to some cheeses, such as black peppers, chives or cranberries.

During industrial production of Emmental cheese, the as-yet-undrained curd is broken by rotating mixers.

A required step in cheese making is separating the milk into solid curds and liquid whey. Usually this is done by acidifying (souring) the milk and adding rennet. The acidification can be accomplished directly by the addition of an acid like vinegar in a few cases (paneer, queso fresco), but usually starter bacteria are employed instead. These starter bacteria convert milk sugars into lactic acid. The same bacteria (and the enzymes they produce) also play a large role in the eventual flavour of aged cheeses. Most cheeses are made with starter bacteria from the *Lactococci*, *Lactobacilli*, or *Streptococci* families. Swiss starter cultures also include

Propionibacter shermani, which produces carbon dioxide gas bubbles during aging, giving Swiss cheese or Emmental its holes (called "eyes").

Some fresh cheeses are curdled only by acidity, but most cheeses also use rennet. Rennet sets the cheese into a strong and rubbery gel compared to the fragile curds produced by acidic coagulation alone. It also allows curdling at a lower acidity—important because flavour-making bacteria are inhibited in high-acidity environments. In general, softer, smaller, fresher cheeses are curdled with a greater proportion of acid to rennet than harder, larger, longer-aged varieties.

3.5.1 Curd processing

At this point, the cheese has set into a very moist gel. Some soft cheeses are now essentially complete: they are drained, salted, and packaged. For most of the rest, the curd is cut into small cubes. This allows water to drain from the individual pieces of curd.

Some hard cheeses are then heated to temperatures in the range of 35–55 °C (95–131 °F). This forces more whey from the cut curd. It also changes the taste of the finished cheese, affecting both the bacterial culture and the milk chemistry. Cheeses that are heated to the higher temperatures are usually made with thermophilic starter bacteria that survive this step—either *Lactobacilli* or *Streptococci*.

Salt has roles in cheese besides adding a salty flavour. It preserves cheese from spoiling, draws moisture from the curd, and firms cheese’s texture in an interaction with its proteins. Some cheeses are salted from the outside with dry salt or brine washes. Most cheeses have the salt mixed directly into the curds.

Other techniques influence a cheese's texture and flavour. Some examples:

- Stretching: (Mozzarella, Provolone) the curd is stretched and kneaded in hot water, developing a stringy, fibrous body.
- Cheddaring: (Cheddar, other English cheeses) the cut curd is repeatedly piled up, pushing more moisture away. The curd is also mixed (or *milled*) for a long time, taking the sharp edges off the cut curd pieces and influencing the final product's texture.
- Washing: (Edam, Gouda, Colby) The curd is washed in warm water, lowering its acidity and making for a milder-tasting cheese.

Most cheeses achieve their final shape when the curds are pressed into a mold or form. The harder the cheese, the more pressure is applied. The pressure drives out moisture—the molds are designed to allow water to escape and unifies the curds into a single solid body.

3.5.2 Ripening

A newborn cheese is usually salty yet bland in flavour and, for harder varieties, rubbery in texture. These qualities are sometimes enjoyed—cheese curds are eaten on their own—but normally cheeses are left to rest under controlled conditions. This aging period (also called ripening, or, from the French, *affinage*) lasts from a few days to several years. As a cheese ages, microbes and enzymes transform texture and intensify flavour. This transformation is largely a result of the breakdown of casein proteins and milk fat into a complex mix of amino acids, amines, and fatty acids.

Some cheeses have additional bacteria or molds intentionally introduced before or during aging. In traditional cheese making, these microbes might be already present in the aging room; they are simply allowed to settle and grow on the stored cheeses. More often today, prepared cultures are used, giving more consistent results and putting fewer constraints on the environment where the cheese ages. These cheeses include soft ripened cheeses such as Brie and Camembert, blue cheeses such as Roquefort, Stilton, Gorgonzola, and rind-washed cheeses such as Limburger

3.6 Production of ginger beer

Ginger beer is a carbonated drink that is flavoured primarily with ginger and sweetened with sugar or artificial sweeteners.

History

Brewed ginger beer originated in England in the mid-18th century and became popular in Britain, the United States, and Canada, reaching a peak of popularity in the early 20th century. Brewed ginger beer was brought to the Ionian Islands by the British Army in the 19th century, and is still made as a local specialty known as "tsitsibíra" (*τσιτσιμπίρα*) by villagers in rural Corfu. Today ginger beer is almost always produced as a soft drink. Ginger beer and ginger ale as soft drinks have been moderately popular in many parts of the world since they were introduced.

3.6.1Brewing

The original recipe requires only ginger, sugar, water, lemon juice and a fungal-bacteria symbioteknown as a ginger beer plant. Fermentation over a few days turns the mixture into ginger beer.

Forms of live culture other than the ginger beer plant can produce a fermented ginger beer. Cultures used include brewers or baker's yeast, lactic acid bacteria, kefir grains, and tibicos. Brewing ginger beer generates carbon dioxide as in beer. The alcohol content when produced by the traditional process can be high, up to 11%, although ginger beer is usually brewed with much less alcohol.

Brewed ginger beer often includes other flavourings, prominently lemon or lime juice. These juices are not merely ornamental, however, as they establish an acidic ph balance for the solution; this helps in both protecting the ginger beer from other cultures, as well as facilitating sugar inversion to increase the availability of the more readily metabolised fructose and glucose. Other, more strictly flavouring-specific, elements have often included: citrus zests; cayenne pepper and other hot spices; and admixtures from other brews such as nettle or dandelion beers.

3.6.2 Ginger beer plant

Ginger beer plant (GBP) is not what is usually considered a plant, but a composite organism consisting of a fungus, the yeast*Saccharomyces florentinus* (formerly *Saccharomyces pyriformis*), and the bacterium*Lactobacillus hilgardii* (formerly *Brevibacterium vermiforme*), which form a symbiotic colony of bacteria and yeast (SCOBY). It forms a gelatinous substance that allows it to be easily transferred from one fermenting substrate to the next, much like kefir grains, kombucha, and tibicos.

The GBP was first described by Harry Marshall Ward in 1892, from samples he received in 1887.Original ginger beer is made by leaving water, sugar, ginger, and GBP to ferment. GBP may be obtained from several commercial sources or from yeast banks.Much of the "ginger beer plant" obtainable from commercial sources is not the true GBP as described here, but instead is yeast alone. This is not legally false advertising because there is no regulation defining GBP.

SELF ASSESSMENT EXERCISES

Why is fermentation important?

4.0 CONCLUSION

Food fermentations are ancient technologies that harness microorganism and their enzymes to improve the human diet. Fermented foods keep better have enhance flavours, textures and aromas. The versatile caterer takes advantage of these qualities to promote her profession.

5.0 SUMMARY

Fermented foods are foods produced or preserved by the action of microorganisms. In this context, fermentation typically refers to the fermentation of sugar to alcohol using yeast, but other fermentation processes involve the use of bacteria such as lactobacillus, including the making of foods such as yogurt and sauerkraut.

Fermentations can basically be performed either by spontaneous fermentation, by back slopping, or by addition of starter cultures. By spontaneous fermentation the raw material, and its initial treatment, will encourage the growth of an indigenous flora.

LAB produce lactic acid and other antimicrobial substances that will inhibit the growth of harmful bacteria, along with reducing the sugar content, thereby prolonging the shelf life of the product.

Starter cultures can basically be classified as; single strain starter and multiple strain starter.

Plant fermentations involve lactic acid, acetic acid, or alcoholic fermentation or a combination of these fermentation types. In alcoholic fermentation, it is mainly yeast (Saccharomyces cerevisiae) and fungi.

Different grains [e.g., maize, rice, sorghum and legumes soybeans,lupins, peas, lentils can be fermented, and most do not involve addition of starter cultures but are fermented by spontaneous fermentation or back-slopping.

Starter cultures for meat fermentation are mainly used in the production of fermented sausages.

Yeasts are involved in both spontaneous and controlled fermentations. For spontaneous fermentation processes, the yeasts are introduced by either the raw materials or via the process equipment.

The benefits obtained by moving from spontaneous fermentations to controlled fermentations are many and, therefore, there seems to be a growing interest in the use of yeasts as purified starter cultures, not only in the control of existing fermentation processes but also in the development of new food products.

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Cheese consists of proteins and fat from milk, usually the milk of cows, buffalo, goats, or sheep. It is produced by coagulation of the milk protein casein. Typically, the milk is acidified and addition of the enzyme rennet causes coagulation. The solids are separated and pressed into final form. Some cheeses have molds on the rind or throughout. Most cheeses melt at cooking temperature.

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Forms of live culture other than the ginger beer plant can produce a fermented ginger beer. Cultures used include brewers or baker's yeast, lactic acid bacteria, kefir grains, and tibicos. Brewing ginger beer generates carbon dioxide as in beer.

6.0 TUTOR –MARKED ASSIGNMENTS

1. Practice making the following:

    a. Yoghurt
    b. Cheese
    c. Bread rolls

2. Form a panel of four people and ask them to taste the above for their organoleptic qualities (colour, taste, texture, smell e.t.c)

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