COURSE GUIDE

FST 202
PRINCIPLES OF FOOD SCIENCE AND TECHNOLOGY

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Introduction

The course, Principles of food science and technology is a core course, which carries three (3) credit units. It is prepared and made available to all degree course students offering Hospitality and Tourism related Programme in the Faculty of Agricultural Sciences**,** Department Economics and Extension at the Nation Open University of Nigeria. Principles of food science and technology is the application of food sciencience and technology principles to the operations of tourism and hospitality industry. This course material is useful in your academic pursuit as well as in your workplace as managers and administrators.

What You will Learn in this Course

This course consists of six modules which are sub-divided into 26 units. This course guide tells you what the course is all about. What course materials you will be using and also suggests some general guidelines for the amount of time you are likely to spend on each unit of the course in order to complete it on schedule. It also gives you guidance in respect of your Self- Assessment Exercises (SAEs) which will be made available in the assignment file. Please attend those tutorial sessions. The course will introduce you to the principles of food science and technology.

Course Aim

The main aim of this course is to arm you with adequate information on the principles of food science and technology in hospitality and tourism management. The course also aims at making you have a greater understanding of the fundamental principles of food science and technology as applicable to hospitality and tourism management. This will prepare the student for a future career in hospitality and related disciplines.

Course Objectives

To achieve the aim set out, the course has a set of objectives which are set out as intended learners' outcome under each unit. You should read these objectives before you study the unit. After going through this course, you should be able to:

- Define food science and technology
- Discuss the chemistry of food
- Evaluate the difference between food science and food technology
- Discuss the microbiology of food
- Analyse how food is packaged and distributed
- Discuss the various classes of food
- Write the functions of each class of food to human
- Discuss the classification of each class of food
- Write the source of each class of food

- Write the major and minor constituents of food
- Analyse the functions of each food major group
- Discuss the structure of the food major groups
- Write the macro and trace elements
- Discuss metabolic functions of each mineral element through the deficiency symptoms
- Discuss the advantages of eating foods containing dietary fibre.
- Discuss vitamins
- Discuss dietary sources of the vitamins
- Analyse the deficiency symptoms of three named vitamins.
- Analyse how foods are distributed and marketed
- Write the importance of food marketing
- Write the societal changes that have impact on food habit
- Analyse the implications of shift of food industry
- Discuss food poisoning and cross contamination
- Discuss the causes of food poisoning
- Discuss food processing by canning, blanching, packaging and cooking.
- Discuss food irradiation
- Write the positive and negative effects of food irradiation
- Discuss the processing of foods by moisture reduction
- Discuss the additives according to functions
- Local processing of alcoholic and non-alcoholic beverages from cereals
- Discuss food preservation
- Discuss the use of modified technology to improve qualities of foods
- Write the major sources of food deterioration
- Analyse Food Adulteration and adulterant
- discuss the nutrient composition of some Nigerian/African foods
- Discuss Environmental hygiene

Working through the Course

This course involves that you devote a lot of time to read and study the contents. Each unit contains self-assessment exercises for this course and at certain points in the course you would be required to submit assignments for assessment purposes. At the end of this course, there is a final examination. I would therefore advice that you attend the tutorial sessions where you would have the opportunity of comparing knowledge with your colleagues.

Course Materials

You will be provided with the following materials
· Course guide
· Study units
· References
· Assignments
· Presentation schedule

STUDY UNITS
There are six modules of 26 units in this course, which should be studied carefully.

Assessment

There are two components of assessment for this course:

· The Tutor Marked Assignment (TMA)
· The end of course examination.

Tutor-Marked Assignment

The TMA is the continuous assessment component of your course. It accounts for 30% of the total score. You will be given four TMA's by your facilitator to answer before you can sit for the final examination.

Final Examination and Grading

This examination concludes the assessment for the course. The examination will account for 70% of total score. You will be informed of the time for the examination.

Summary

This course intends to provide you with underlying knowledge of principles of food science and technology for the study of Hospitality Management and Tourism.

MODULE 1

UNIT 1 PRINCIPLES OF FOOD SCIENCE AND TECHNOLOGY

CONTENTS

1.1 INTRODUCTION

Foods are materials, which in their naturally occurring, processed or cooked forms, are consumed by human beings for their nourishment, sustenance and enjoyment. Food items are food grains such as cereals e.g. wheat, rice, sorghum, millets, etc.; legumes like red gram, black gram, green gram, beans; horticultural produce e.g. fruits, vegetables, spices, condiments etc., livestock produce e.g. meat, egg, milk etc., and fish, prawns, crabs etc. Beverages like tea, coffee, cocoa etc. are also part of food.

Food is anything eaten to satisfy appetite, meet physiological needs for growth, maintain all body processes and supply energy to maintain body temperature and activities. It is any substance, processed, semi-processed or raw, that is intended for human consumption, and includes drink and any other substance which has been used in the manufacture, preparation or treatment of "food", but does not include cosmetics or tobacco or substances used only as drugs. Since foods differ clearly in nutrient content, they are classified on the basis of their composition and sources.

A normal healthy diet should contain fat, carbohydrates, protein, and a range of essential macronutrients and micronutrients, in the form of dietary fibre, minerals and vitamins.

Micronutrients: These are nutrients that are required in minute quantity by an organism for normal growth and development e.g. a vitamin.

Macronutrients: These are elements required in large quantity for the normal growth and development of an organism.

Food sources in their natural form are cultivated, reared, captured or cultured. Some foods can be taken in raw form while most need some kind of processing to introduce desirable characteristics in them to make them acceptable, edible and digestible.

Food Science and Technologists applies scientific knowledge to the selection, preservation, processing, packaging, distribution and use of safe nutritious and wholesome food.

1.2 Learning Outcomes

By the end of this unit, you will be able to:

- Define food science and technology
- Discuss the chemistry of food
- Evaluate the difference between food science and food technology
- Discuss the microbiology of food
- Analyse how food is packaged and distributed

1.3 Food Science

Food Science is the discipline in which the Biological and Physical Sciences and Engineering are used to study the nature of Foods, Causes of their deterioration and the principles underlying Food Processing.

It is the study of the physical, biological, and chemical makeup of food. Food Scientists and Technologists apply many scientific disciplines, including Chemistry, Engineering, Microbiology, Epidemiology, Nutrition, and Molecular Biology to the study of food to improve the safety, nutrition, wholesomeness, and availability of food. Food Scientists develop ways of processing, preserving, packaging, and/or storing food, according to industry and government specifications and regulations.

Food Technology is the application of Food Science to the selection, preservation, processing, packaging, distribution and use of safe nutritious and wholesome food.

1.3.1 Scope of Food Science and Technology

Food Science and Technology include the following major areas of specializations:

1.3.2 The Chemistry of Food

Food chemistry is the study of the composition of foods, properties and how they interact with each other and the environment. It may also include Food Analysis which is subdivided into two main areas, qualitative and quantitative analysis. The qualitative analysis involves the determination of unknown constituents of a substance, and the quantitative analysis is the determination of the relative amounts of such constituents.

The major chemical classes of food are: Proteins, carbohydrates, fats, minerals and vitamins.

1.3.3 Food Microbiology

Food microbiology is the scientific study of microbes and their effects in food. Microorganisms commonly found in food systems are bacteria, fungi, rarely viruses and parasitic organisms.

1.3.3.1 Bacteria

Bacteria are employed in the processing of many foods and food products. Bacteria cause food spoilage and food borne diseases/infection and also improve food flavour and nutrition. Bacteria are used in the fermentation of many dairy products people consume every day such as yoghurt, cheese. The lactic acid bacteria produce lactic acid, which turns the milk sour, obstructs the growth of disease-causing bacteria, and gives a desirable flavour to the resulting yogurt. For cheese, the bacteria ferment milk sugar to lactic acid.

1.3.3.2 Fungi

Fungi are single-celled or multicellular organism without chlorophyll that reproduces by spores and lives by absorbing nutrients from organic matter. Thousands of different types of fungi grow on and absorb food from substances such as soil, wood, decaying organic matter, or living plants and other organisms. They range from tiny, single-celled organisms invisible to the naked eye to some of the largest living multicellular organisms. Fungi are of immeasurable value to mankind and have proven extremely valuable in the synthesis of antibiotics and hormones used in medicine and enzymes used in certain manufacturing processes. Although some fungi are beneficial to man in terms of production of enzyme and by being used for food (edible fungi) quite a lot of them are known to spoil food matrices.

The mycelium of *Aspergillus niger* produces clusters of root-like hyphae, called rhizoids, which penetrate the organic material, secreting enzymes and absorbing water and the digested sugars and starches.

Yeasts are small single-celled fungus. They ferment carbohydrates and reproduces by budding. The most cultivated yeast is the genus Saccharomyces. Brewer's yeasts are strains of *S. cerevisiae* and are used industrially in a wide range of fermentation processes. Medicinally, it is used as a source of vitamin B-complex vitamins and thiamine and in the production of various antibiotics and steroid hormones. It is also used inthe productiuon of wines, beers, spirits, and industrial alcohol.

1.3.3.3 **Viruses**

Viruses are intracellular obligate parasite which can trigger dangerous infections in humans when they contaminate our food. Foods that are handled manually and are not processed before consumption are at particular risk of viral contamination. Norovirus and hepatitis A are the most important foodborne diseases. Viruses are 10- 450 nm in size; cannot reproduce without a living host; attack only susceptible host cell lines; infect plants, animals, and bacteria; and have the capacity to produce specific diseases in specific hosts. Transmission occurs in foods, water and air. Viruses that infect bacteria are called bacteriophages. Viruses consist of a DNA or RNA core surrounded by a protein coat. Because they lack all the apparatus for normal cellular metabolism, they must utilize the cellular machinery of the host cell in order to grow and divide. Once they invade a host cell, however, viruses can multiply very rapidly.

Viruses are important in food for three reasons. Some are able to cause enteric disease and thus, if present in a food, can cause food borne diseases. Hepatitis A and Norwalk viruses have been implicated in food borne outbreaks. Several other enteric viruses, such as Poliovirus, Echovirus, and Coxsackievirus, have the potential of causing food borne diseases.

Table 1. Human Intestinal Viruses with High Potential as Food Contaminants

SN	Types of Viruses	Examples
1	Picornaviruses	Polioviruses Coxsackievirus A Coxsackievirus B Echovirus Enterovirus
2	Reoviruses	Reovirus Rotavirus
3	Parvoviruses	Human gastrointestional viruses
4	Papovaviruses	Human BK and JC viruses
5	Adenoviruses	Human adenoviruses

1.3.3.4 **Parasitic Organisms**

A number of parasitic worms can also be transmitted by food to cause diseases in humans. Cestodes are flatworms that inhabit the intestinal tract, heart, and lungs of animals. Beef, swine, dogs and other canine species, bears, and fish can all harbour tapeworms and flatworms, which can be transmitted to and can infect humans. Trematodes are non-segmented flatworms that possess a mouth and oral sucker and depend on a snail as an intermediate host before infecting humans by being ingested in drinking water or aquatic plants. Intestinal flukes, pyriform worms from fish, sheep and Chinese liver flukes, and oriental lung flukes are all examples of food-transmitted parasites. Nematodes or true roundworms also can be transmitted from animals to humans. Eggs carried in excrement from roaches and dung beetles ingested by cattle, sheep and hogs contaminate humans. Trichinosis is an inflammation of the muscle tissue caused by ingesting the worm Trichinella spiralis. Pork is the most common vector. Capillary worms, whipworms, and pinworms are other examples of nematode parasites. Protozoa are microscopic single-celled animals, which can be taken in with food or water to cause human illness. *Entamoeba histolytica*, *Toxoplasma gondii*, *Balantidium coli*, and *Giardia lamblia* are the most common food borne protozoan parasites.

1.3.4 Food Packaging

Food packaging is necessary to make sure the food remains wholesome and makes it easier to handle and protects it from harsh environmental conditions, such as extreme temperature during transport. It prevents the food from the contaminants (microorganisms and chemicals) that could contaminate it, and helps prevent physical and chemical changes and maintain the nutritional qualities of food. The type of food and the processing method used often influence the choice of packaging. For instance, since oxygen makes fats go rancid, oils are packaged in containers that are impermeable to oxygen. On the other hand, oxygen-permeable plastic wraps allow fruits and vegetables to “breathe” and ensure that meats will maintain a vibrant red colour. Metal and glass containers have traditionally been used in canning because these materials can withstand the high temperatures and changes in pressure that are involved in this processing method. Glass is often used for packaging heat-sterilized foods because it is impermeable to oxygen and water and does not change the flavour of the food. Glass is transparent, enabling the consumer to see the product inside. However, glass is not impact-resistant and is relatively heavy.

Plastic containers are lightweight and unbreakable. plastic has become an extremely common material for use in food packaging and most plastics used in food packaging are heat resistant so that they can go through high-temperature sterilization processes. Plastic is made into a wide variety of shapes, including bottles, jars, trays, and tubs, as well as thin films that are used as bags and wraps.

Papers alone can be used in packaging certain dry foods like flour and sugar. However, when paper is coated with plastic or other materials to make it stronger and impermeable to water, it can be more widely used. Paperboard is often used for cartons, and plastic-coated paperboard for packaging frozen foods.

1.3.5 Food Processing and Preservation

Food Processing includes all the steps that food goes through from the time it is harvested to the time it gets to the retailer. Some processing methods convert raw materials into a different form or change the nature of the product, as in the manufacture of sugar from sugar beets, oil from corn or soybeans, etc. Processing may also involve an extremely complex set of techniques and ingredients to create ready-to-eat foods.
Food Preservation refers specifically to the processing techniques that are used to keep food from spoiling. Spoilage is any change that makes food unfit for consumption and it includes chemical and physical changes such as bruising and browning; infestation by insects or other pests; or growth of microorganisms, such as bacteria, yeast, and molds and even viruses.

Food Processing and Preservation therefore is a branch of Food Technology that is concerned with the transformation of raw food (animal, vegetable, or marine materials) into tasty, nutritious and safe food products. It also provides a means of creating products that are convenient for consumers, like those that are ready to eat or require minimal preparation and cooking. Food Processing and Preservation techniques together with modern food distribution networks make seasonal crops available all year round.

Self- Assessment Exercises 1

1. Define Food science.

2. List the microorganisms commonly found in foods

1.4 Food Distribution and Marketing

Food Distribution and marketing network brings food products from the manufacturers/producers to various retail outlets across the globe. Modern high-speed methods of transportation like trucks, trains, and planes and reliable methods of environmental control especially refrigeration enable even perishable food to be transported great distances. Food Distribution networks help satisfy consumer demand for variety, making available, even in remote areas, foods that are not locally grown or processed. Through various distribution channels, food makes its way to food retailers, such as restaurants, fast food outlets, supermarkets, convenience stores, specialty shops, drug stores, and some department stores, minimarkets and open market.

a. What is food marketing?

Marketing encompasses a series of activities involved in moving the goods from the point of production to point of consumption. Many scholars have defined agricultural marketing and incorporated essential elements of time, place, form and passion utility. The earliest usage of market put market as a physical place where buyers and sellers gather to exchange goods and services. To the marketers, a market is seen as the set of all individuals and organizations who are actual and potential buyers of a product or service.

1.5 Food Situation in Nigeria

Majority of Nigerians are subsistence farmers. In the North they produce sorghum, millet, and rear cattle while they cultivate maize, rice, and yams in the south. Across the nation they they produce Cassava, legumes, tomatoes, plantains, sugar cane and livestock like poultry, goats, and sheep. Agriculture account for 26 percent of Nigeria's GDP and engages 3 percent of the economically active population.

Palm oil became an export crop to Europe in the early 19th century but later Cocoa and groundnuts grew in importance, surpassing palm oil as export crops in the early 1950's. The Principal crops in 1999 (annual output in tonnes) included: cassava (33.1 million); sorghum (7 million); millet (5.96 million); peanuts (3 million); and sugar cane (675,000). Palm oil and kernels, yams, and maize are also important. Livestock included 24.5 million goats, 19.6 million cattle and 14 million sheep.

Food production is seasonal in Nigeria and during the periods of harvest, a false impression of surplus is given but within a short time, they are exhausted through direct consumption, wastages, deterioration and spoilage. This is all the more so because adequate processing, preservation and storage facilities are not available during periods of this "surplus". In developed countries, constant food supply is ensured by extra-seasonal conservation and storage of food products but in Nigeria where these facilities are absent, food consumption and industrial production patterns are markedly seasonal.

Most Foods is perishable naturally. According to a study carried out in 1996, losses in food produce were as high as 25 – 65% for plantains, tomatoes, oranges, banana, leafy vegetables and citrus fruits. Apart from physical losses, nutritional losses were also recorded: as much as 15 – 20% of Vitamin C was reportedly lost during transportation between the farm gate and the eventual consumers. A survey conducted by the Central Bank of Nigeria in 1994 reported losses in agricultural output in the following food items: maize (6.852 million tons), cassava (22.3 million tons), and beans (1.47 million tons). These shows massive losses in farm produce as well as income if the commodities have been sold.

The fact that fresh foods cannot be found at all times and in all places makes food processing and preservation essential for all year round supply of wholesome food.

The major problem facing the producers has always been that the crops grows and generally mature for harvesting during a single short period of the year mostly at the beginning of dry season. The best solution to this producer's problem is citing of specialized food processing and preservation plants close to the producing areas.
Nigeria needs modern technology to overcome her food problems and this new technology is important because it will permit the optimum utilization of available resources and improvements in food products that are peculiarly Nigerian if not her citizens will depend on foreign products. New and improved processing methods as has been done of late for garri (fermented cassava meal), ogi (fermented corn meal) and iru (Parkia biglobosa) and some alcoholic beverages like beer, pito, Burukutu etc. and non-alcoholic beverages such as Tsobo (zobo), Kunnu, fruit drinks, etc.

Self- Assessment Exercises 2

1. List five crops grown across Nigeria

2. State the importance of food distribution to consumers

1.6 SUMMARY

Food Science and Technology (FST) involve the processing, preservation, distribution, and marketing of foods as well as the metabolism and utilization of food in the body.
Food Science is the discipline in which the Biological and Physical Sciences and Engineering are used to study the nature of Foods, Causes of their deterioration and the principles underlying Food Processing. Food Technology is the application of Food Science to the selection, preservation, processing, packaging, distribution and use of safe nutritious and wholesome food.
Foods contain micro and macro nutrients. Microorganisms are essential in the processing, spoilage and preservation of food. The distribution and marketing of processed food are essential to make foods accessible. Food production and marketing are seasonal in Nigeria.

1.7 References/Further Readings

Walker, A.F (1990). Applied Human Nutrition. Aspen Publishers. 300 pages.

Bubel, M., Bubel, N and Art, P. (1991). Root Cellaring: Natural Cold Storage of Fruits and Vegetables. 2nd ed.

Coxe, A. H and Coxe, A. H (1997). The Great Book of Sausages. Overlook, 1992, 1997. Recipes, Instructions for Making 45 Varieties, and the History and Ingredients of 600 Types of Sausages.

Belitz, H.D., Grosch, W., Schieberle, P and M.M. Burghaghen, M.M (2004). Food Chemistry. Springer, 1071 pages

Hutkins, R (2006). Microbiology and Technology of Fermented Foods – A Modern Approach. Blackwell Publishing Professional, 488 pages

International Commission for Microbiological Specifications of Foods (ICMSF) (1996). Microorganisms in Foods - Characteristics of Microbial Pathogens – Springer. 1996. 524 pages

Marriot, N.G. and Gravani, R (2006). Principles of Food Sanitation, 5th Edition. Springer, 413 pages

Swaroop, K. R. and Giddaiah, R (2020). Societal Changes and Its Impact on Food Habits. *International Journal Of Scientific & Technology Research,9(2):246-271.*

Kumar, A (2019). Food Preservation: Traditional and Modern Techniques. *Acta Scientific Nutritional Health*, 3(12): 45 – 49

Lianou, A., *et al*., (2016). "Microbiological spoilage of beverages". In The Stability and Shelf Life of Food. (Subramanian, P. ed.) Second Edition Woodhead Publishing, India, 3-42.

Jay, J.M., Loessner, M.J. and Golden, D.A (2005). Modern Food Microbiology, 7th edition, Springer food science text series, 790 pages

Sancho-Madriz, M F (2003). "Preservation of Food". In Encyclopedia of Food Sciences and Nutrition. 2nd edition, Elsevier science Ltd publisher

Banti, M (2020). Food Adulteration and Some Methods of Detection, Review. *International Journal of Research Studies in Science, Engineering and Technology*, 7(4):9-19.

1.8 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. Food Science is the discipline in which the Biological and Physical Sciences and Engineering are used to study the nature of Foods, Causes of their deterioration and the principles underlying Food Processing. It is the study of the physical, biological, and chemical makeup of food.
2. . Microorganisms commonly found in food systems are bacteria, fungi, rarely viruses and parasitic organisms.

Answers to Self-Assessment Exercises 2

1. Cassava, legumes, tomatoes, plantains and sugar cane
2. Distribution help satisfy consumer demand for variety, making available, even in remote areas, foods that are not locally grown or processed.

UNIT 2 FOOD CLASSES

Table of Content

2.1 Introduction

This unit discussed the various classes of food. Food classes include: Carbohydrates, Protein, Minerals, lipids, and Vitamins. Carbohydrate is an energy yielding nutrient, the largest nutrient in the food after water. It has been reported that carbohydrate accounts for about 75 percent of the energy in the plants. Protein can supply energy (4 kilocalories per gram), promotes growth and maintain the body tissues.

The minerals are inorganic substances drawn from the soil by plants. They are supplied by plants and animals that have already consumed plants. Though they are inorganic substances, many of them are found as components of complex organic substances in the foods.
Vitamins are organic substances needed in small amounts and they perform a specific metabolic function. They are supplied from the dietary sources.

Lipids become most predominant after water and carbohydrates. They are very visible fats and oils such as butter margarine, vegetable oils. There are also the invisible oils and fats in fibres of meat and in egg yolk, in milk, in grain cereals and nuts.

2.2 Learning Outcomes

By the end of this unit, you will be able to:

- Discuss the various classes of food
- Write the functions of each class of food to human
- Discuss the classification of each class of food
- Write the source of each class of food

2.3 Carbohydrates

Carbohydrate is one the classes of food and an energy yielding nutrient and the largest nutrient in the food after water. It has been reported that carbohydrate accounts for about 75% of the energy in the plants.

2.3.1 Classification of Carbohydrates

(a) **Monosaccharides**

Monosaccharides are simple sugars and the most important of them are glucose, fructose and galactose. Glucose is also known as grape sugar, Fructose is found in fruits and vegetables honey and sugar cane and Fructose is sometimes referred to as laevulose. Galactose is found in milk. Monosaccharides are end products of digestion of dissacharides and polysaccharides.

(b) **Dissacharides**
Dissacharides are sugars that yield two Monosaccharides on hydrolysis. The most common and important disaccharides are sucrose, maltose and lactose. Sucrose yields fructose and glucose when hydrolyzed.
(c) **Polysaccharides**
The polysaccharides are sugars that yield more than two monosaccharides. The principal forms of polysaccharides are starch, dextrin, glycogen, and cellulose. Others are insulin, agar, pectin, and peptic substances. This later group is of little or no nutritional importance to the body.
The most important of the polysaccharides to human nutrition is starch. It is found in cereal grains, roots, bulbs and tubers.

2.3.2 Functions of Carbohydrate

(a) Source of Energy
Carbohydrate is the most inexpensive source of energy in the body. The glucose produced from the breakdown of carbohydrate is the only source of energy to the nervous tissue. Through the process of gluconeogenesis, glucose is produced from part of fat and from some amino acids. With this the nervous tissue can still obtain its need for glucose even without dietary intake of carbohydrate. However, when the glucose level in the blood falls below normal, the brain has problem with the supply of glucose - its only energy source.

(b) Dietary Essentials
Apart from carbohydrates, fat and protein could be used as a source of energy. A diet should not be completely free of carbohydrate because recent evidence has shown that a diet of protein and fat, free of carbohydrate produces many undesirable symptoms. It is known that individual on carbohydrate free diet usually develops symptoms that resemble those of starvation. They are found to lose large amounts of sodium, unable to prevent breakdown of body protein, develop ketosis (excessive breakdown of protein), dehydration, tiredness and loss of energy.
(c) Carbohydrates and some of the products derived from carbohydrates serve as precursors of some important compounds (nucleic acids and connective tissue matrix) in the body.

2.3.3 Sources of Carbohydrate
Carbohydrates are mostly found in plants, eggs, cereals, roots and vegetable. Tubers, corn, sugar-cane, fruits and the cereals and cereal products have been found to form the largest fraction of the diet of man.

These cereal and their products include wheat flour, pastries, bread, cakes, dry cereals and so on. The vegetables parts like the root, tuber, leaves, fruits and seeds contain carbohydrate. Roots and tubers like Yams, potatoes, cocoyams are rich sources of carbohydrate.
Legumes are also good sources of carbohydrates. Ripe fruits and sugars, syrups, molasses, jams and jellies, beverages, candies and honey are good sources of carbohydrates.

2.3.4 Dietary Requirements of Carbohydrate

The body can perform its functions even when there is considerable low supply of carbohydrates. Hence it is not possible to establish a dietary standard for carbohydrate. Since the only source of fuel for the brain is from glucose, carbohydrate is taken so that the brain can get us fuel. Diets that are free from carbohydrate cannot be taken for long since they are unpalatable and they also lead to low intake of sodium, ketosis, involuntary dehydration and some other undesirable metabolic responses.

Self- Assessment Exercises 1

1. State the sources of carbohydrates
2. List the classes of carbohyradtes

2.4 Protein

2.4.1 Chemical Composition

Proteins are complex organic substances that are made of amino acids. They are about twenty different naturally occurring amino acids that are used for the synthesis of proteins. The structural formula of an amino acid is given as

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   COON
    I
H--C –R
    I
   NH2
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It contains a carboxyl group (COON), a hydrogen atom, an amino group (NH,) and an amino acid radical (R) attached to a carbon atom. The difference in amino acids is brought about by the difference in the amino acid radical (R) because the other components are the same with all amino acids.

The amino acid radical (R) varies from a single hydrogen (H) atom found in glycine, the simplex amino acid, to a longer carbon chains of 1 to 7 carbon atoms. The amino acid radicals are even in form of benzyl ring in some aromatic amino acids such as tyrosine and phenyalanine. Some amino acid radicals such as in cysteine and methionine also contain sulphur, some amino acids contain a second nitrogen atom and they are called dibasic amino acids and the examples arc tryptophan, lysine, histidine and arginine.

The nitrogen of the amino group is a very important characteristic factor in proteins since it is not found in other nutrients. It varies from 15% to 18% of the amino n=acid molecule. It is 15% in milk protein, 16% in wheat, 17% in cereals and 18% in nuts.

Some of the naturally occurring amino acids are essential while the others are non-essential

a. Essential Amino Acids are Leucine, isoleucine, lysine, methionine, phenyalanine, threoneine, tryptophan, valine and histidine.
b. The non-essential amino acids are glycine, alaninie, arginine, aspartic acid, asparagines, glutamine, glutamic acid, cystieine, proline, scrine, tyrosine.
c. There are some related compounds that are sometimes classified as amino acids. They are: Cystine, thyroxin, norleucine, hydroxyl-glutamic acid, hydroxylysine and hydroxyl-proline.
Glysine has been found to be essential for chicks and arginine to be essential for birds and rats.

In the synthesis of protein, the amino group of an amino acid reacts with the carboxyl group of another amino acid to form a peptide bond.
The properties of the protein are determined by the types of the amino acid it contains and the sequence of these amino acids. The types and the sequence of the amino acids in the protein also determines the three dimensional configuration of protein which determines both the enzymatic and catalytic activities of a protein.

2.4.2 Sources of Protein

Proteins are found in both plant and animal. Animal proteins are superior to plant proteins in form of their amino acids composition and digestibility. The animal proteins have more essential amino acids than the plant proteins.

The animal sources are meat and meat products, milk and milk products, eggs, fish. Some plant sources are beans, peanuts, whole wheat bread, soybeans and so on.

2.4.3 Functions of Protein

a. Promoting growth and maintenance of the body tissues: Protein prompts growth and maintains the body tissues when some tissues are worn out.
b. Formation of essential compounds in the body: The enzymes, hormones, insulin, thyroxin and adrenaline are all proteins. Heamoglobin that carries oxygen to the cells for respiration is also protein. In blood clotting, prothrombin and thromboplastin that are used are all proteins.
c. Maintenance of body neutrality: Since amino acids contain both basic and acid groups that is, they are amphoteric and help in maintaining body neutrality. Their presence in the body therefore helps to prevent accumulation of too much acid and base which could interfere with normal body functioning.
d. Stimulation of antibody formation: the antibodies that are responsible in combating infection in the body are proteineous. Enzymes are responsible for the detoxification of poisonous materials in the body. Protein depletion in the body affects the resistance of the body against infection and reduces the ability of the body to detoxify poisonous materials.
e. Transportation of nutrients: protein plays an essential role in the transportation of nutrients from intestine across the intestinal walls to the blood, from blood to the tissues and across the cell membrane into the cell. Most of the carriers of nutrients are proteins. Depletion of proteins reduces the absorption and transportation of some nutrients in the body.

2.4.4 Denaturation of Protein

Proteins in their native forms have three dimensional configurations that determine its enzymatic and catalytic activities. This configuration changes when protein is denatured thereby leading to the loss of the enzymatic and catalytic activities.

The denaturing agents are:

a. Heat
b. Vigorous agitation such as whipping or shaking
c. Organic solvents such as ethanol
d. Excessive alkalinity or acidity
e. Salts of heavy metals
f. Alkaloidal agents such as tannic acid and picric acid.

Denaturation of proteins causes the destruction of enzymes, coagulation, gel formation and curdling. In some food processing the denaturing of enzymes is deliberate to prevent deterioration.

2.4.5 Dietary Requirements of protein

There are two ways in which we can estimate the dietary requirements of proteins. They are:

a. Minimum amount of protein required to promote growth in children and to maintain nitrogen balance in adults.
b. Calculation of losses of nitrogen through urine and feaces on a protein-free diet, after allowances have been given for obligatory losses through skin, sweat and worn out cells.
More amounts of proteins per kilogram of body weight are consumed by growing children, pregnant women and lactating mothers. There is no evidence of adverse effects of intake of protein above the minimum requirements. The protein required in the body must be able to meet the body needs for growth, maintenance of body tissues, compensate for losses through urine, faeces, worn out tissues and various body secretions and excretions.

Self- Assessment Exercises 2

1. List the essential amino acids
2. What are the functions of proteins

2.5 MINERALS

2.5.1 Classification and Body Composition of Mineral

Minerals in the body are grouped as

i. Macro nutrient /elements or Major minerals
ii. Micro nutrient/elements or Trace elements

Macro nutrient are minerals that are required in relatively large amounts in the body. They include calcium, phosphorous, potassium, sulfur, sodium, chlorine, magnesium etc. The major electrolytes of the body water have been identified as sodium, chlorine and potassium.
Micro nutrient/elements or Trace elements are those minerals that are present in the body in amounts less than 0.005 percent of the body but are useful to the body. They are iron, iodine, zinc, selenium, manganese, copper, fluorine, chromium, cobalt and molybdenum.
The amounts of mineral that are present in the body are very small, though minerals play significant roles in the body. The mineral elements in the body constitute only about 4 percent of the bodyweight and most of the minerals are in the bones.

2.5.2 Functions of Minerals

There are mainly two major functions of minerals in the body. They are:
a. Constituents of the body tissues
b. Regulators of some body functions
Calcium, magnesium and phosphorous are important constituents of the bones and teeth. Sodium, chlorine and potassium are important electrolytes in the body fluids. Iodine is found in the thyroid gland while magnesium is a component of the muscles and blood. Minerals are parts of many enzymes and hormones. There are copper and iron in cytochrome oxidase and zinc in carboxypeptidase. Iron is part of

heamoglobin that transport oxygen to the cells and transports carbon dioxide away from the cells.
The minerals act as regulators and they are necessary to some body functions. Minerals play important roles for the proper functioning of the nerves. Exchange of sodium and potassium ions facilitates the transmission of a nerve impulse while altering the concentration of calcium, magnesium, sodium and potassium in the fluids of nerve cells has been found to disrupt the ability of the nerves to transmit impulses.
The neutrality of the body fluids or the acid-base balance is maintained by some minerals that can generate acid and alkali media.
Chlorine, phosphorus and sulphur that are found predominantly in protein foods like eggs, meats and in cereal products, generate acid medium.
Some of the minerals found largely in fruits and vegetables are calcium, iron, magnesium, potassium and sodium. For cells to function and survive, the neutrality of the body cells must be maintained. Minerals are involved in the osmotic pressure of the body fluids that have a lot of effects on the movements of nutrients.
Some reactions in the body require sonic levels of acidity and alkalinity and it is facilitated by minerals. The contraction of muscles depends on the presence of calcium, sodium, potassium and chlorides.
Minerals serve as catalysts in some reactions in the body. Calcium is important in blood clotting and absorption of Vitamin B12, zinc is important in the production of insulin, sodium and magnesium are important in carbohydrate absorption, and minerals are part of the catalyzing enzymes in the metabolism of carbohydrates and fats.

2.5.3 Macro nutrient/Elements

2.5.3.1 Calcium

Calcium is found mostly in bones and teeth and it’s the most abundant mineral in the body. It gives the rigidity and hardness of both bones and teeth. Calcium ions are concerned with all cell functioning. They are involved in the clotting of blood. It plays a corrective role in conditions of excess presence of potassium, magnesium or sodium in the body. The deficiency of calcium and phosphorous is implicated in rickets in small children. Osteomalacia, the adult rickets, may also be due to deficiency of calcium as well as deficiency of phosphorous and vitamin D. The deficiency of calcium is also implicated in the occurrence of osteoporosis, the thinning of bones in old people. Low level of calcium in blood and fluids in the body may interfere with response of nerves to stimuli.
There is always a dynamic equilibrium between the calcium in the blood and that in the bones. The calcium in the bone dissolves constantly into blood under the influence of the cells called Osteoclasts. This has been found to allow bone growth in childhood and adolescence. It also provides for maintenance and adjustment of bone shape to meet stresses

on the skeleton in the action of the adults. As a result of the urinary excretion of calcium, there is the need for regular dietary intake of calcium. The deficiency of vitamin which regulates the absorption of calcium from food in the intestines into the blood can result into serious problems of deficiency of calcium. If a pregnant woman suffers deficiency of such Vitamin, it can result into deficiency of calcium, which can later result into osteomalacia in the child after birth.

The most important sources of calcium are milk and milk products and cheese. Other sources of calcium are tinned fish, green vegetables, fortified with bread. Excessive intake of calcium can result into hypercalceamia. This occurred when fortification of baby foods was done with Vitamin D without restriction.

2.5.3.2 Phosphorous

Phosphorus occurs in the body generally with calcium and they contribute to the supportive structures of the body. Phosphorous is important in chemical reactions with protein, fats and carbohydrates so that the body may have energy. Phosphorous exists as soluble phosphate ions in blood, lipids, proteins, carbohydrates and energy transfer enzymes.

Some Vitamins have been found to be effective only when they combine with the phosphate in the body. Phosphorous is an important component of nucleic acids and nucleoproteins which are responsible for cell division, reproduction and transmission of heredity traits. Phosphorous has been found to be concerned with brain and nerve metabolism.

Phosphorous combines with calcium to give rigidity to the bones and teeth. Phosphorous forms an important component of enzymes and coenzymes that are responsible for respiration in tissue. Phosphorous is found in cereals and meats of all kinds, legumes, nuts, eggs, milk and its products.

2.5.3.3 Potassium

Potassium exists as a cation bound to protein in the body and Combine with sodium to influence the osmotic pressure and also contributes to the normal equilibrium of body fluids. Potassium has been found to be related to the other minerals in metabolism. Deficiency of potassium leads to retention of sodium. Deficiency of magnesium also results into depletion of potassium. Dietary lack of potassium does not cause deficiency of potassium. Body potassium may be reduced through fasting, starvation, infectious diarrhoea and vomiting, severe protein, calorie malnutrition and diabetics.

2.5.3.4 Sodium

Sodium exists as cations in intracellular fluids and help to maintain osmotic pressure equilibrium of the fluids and the pH of body fluid volume. Sodium is used for tissue formation, nerve transmission and muscle contraction. Sodium and potassium cations together with anions of phosphates, carbonates and citrates are responsible for alkalinity of the bile and pancreatic juice and they help to stabilize the pH of the blood.

Sodium deficiency results in "heat fatigue" (muscular weakness), drowsiness and mental confusion. Sodium is consumed in the food as sodium chloride and 6 to 8grams are recommended as daily intake. Vomiting, renal disease, adrenal insufficiency, diarrhea and profuse sweating lead to loss of sodium from the body. Loss of sodium accompanied by loss of water causes muscle cramps and low Blood Pressure.

2.5.4 Micro nutrients/Elements

2.5.4.1 Iron

It is difficult to absorb iron from food and to excrete it through urine, rather little iron absorbed from food is retained in the body is in form of haemoglobin and myoglobin. Iron is important in the oxidation of food and release of energy. Iron is also involved in the transfer of electrons.

About 25 percent of the iron in the body is stored as ferriten. Only very small amount of iron is absorbed into the blood stream so also, only very little ion is lost in the body except during injury and menstruation. During the manufacture of new red blood cells in the bone marrow of growing children and pregnant women more iron is absorbed to respond to this increase in need.

The condition of inadequate haemoglobin which jeopardizes oxygen supply in the cells called Anaemia is as a result of deficiency of iron. Children and adolescents are at the risk of the deficiency of iron during the period of increase in blood volume, girls and women due to menstruation, and women undergoing a succession of pregnancies. Ascorbic acid and products of protein digestion favours the absorption of iron. The formation of insoluble salts from the reaction of oxyalate and phaytate ions with the free fatty acids present in the intestines reduce the absorption of iron. A recommendation of 10mg per day of iron for adult men and 12mg for women in child bearing years has been made. The recommendations of iron during adolescent, pregnancy and lactation have been given respectively as 12 and 13mg per day. Liver and black sausages are good sources of iron. All flesh foods and eggs also contain useful amount of irons. **2.5.4.2 Iodine**

Iodine is found in the thyroid gland of the body where it is bound as an essential component of thyroxine. A lack of iodine in the body results to Goitre and the thyroid gland in an attempt to compensate for this deficiency of iodine becomes over stimulated and this leads to the enlargement of the gland. Women and girls are more susceptible to goiter than boys and men.

Cretinism (occurs when there is acute deficiency of iron in thyroid secretion in childhood which leads to retardation of growth in children and development of ape-like appearance). Iodine is also very important for normal production and lactation. Pigs that lack iodine have been found to produce hairless young ones. A sufficient intake of the diet is assured by the use of iodine salt.

Self- Assessment Exercises 3

1. What are the functions of minerals
2. State the micro-nutrients in foods

2.6 VITAMINS

2.6.1 Classification of Vitamins

Vitamins are organic substances that are required in small quantity. They perform a specific metabolic function in the body. Some substances that are considered as vitamins for some animals may not be vitamins for some other animals which can synthesize these substances. For instance vitamin C is considered as vitamins for human beings, monkeys and guinea pigs but it is synthesized by rats, rabbits, dogs and other animals.

The vitamins are manufactured by the plants from the nutrient available to them in the soil. There are eleven water soluble vitamins clasified into vitamin B group and Vitamin C. The Vitamin B group are: Thiamin (B), Inciton, Cholin, Riboflavin (B), Pantothenic acid, Biotin, Pyridoxin (B1), Niacin (I32), Folacin or Folic acid, amd Cobalanin (Br).

The fat soluble Vitamins are: Vitamins A, D, E, and K.

Precursors (Pro-Vitamins) and Antagonest (Anti-Vitamins) are some compounds that are related to Vitamins and are converted in the body to the active forms of the vitamins. Carotene, the precursor of vitamin A is converted to vitamin A in the intestinal wall. 7- dehydrocholesterol is converted to Vitamin D in the skin and to the active form in the liver and kidney when the body is exposed to the sunlight energy especially early in the morning. Tryplophan is converted to Niacin in the liver. The anti-vitamins prevent the functioning of the vitamins by refusing to be replaced by the active vitamin in compounds that will allow the vitamins to perform their roles.

2.6.2 Causes of Vitamin Deficiencies

a. Inadequate supply of the vitamins from the diet. The vitamin requirements of people vary.

b. The failure of the body to absorb vitamins required by the body may cause the deficiency of the vitamins in cells. If a person cannot secrete enough bile, the absorption of fat soluble vitamins will be lower than required. Very rapid passage of food through the intestinal tract may also reduce the absorption of nutrients.

c. Increased need for a vitamin may also precipitate the deficiency of that vitamin if additional intake over and above the original intake is not made.
d. Losses of vitamin through processing of the food may also cause deficiency of the vitamins in the diet consisting of the foods.

2.6.3 Fat Soluble Vitamins

2.6.3.1 Vitamin A

Vitamin A occurs in several forms in nature; as retinol in mammals and saltwater fish, as dehydroretinol in fresh water fish, as pro-vitamins (Precursor) known as Carotenes. Vitamin A is supplied to the body through dietary intake or supplements. Excess amount of vitamin A consumed over the required amount in the body is stored in the liver for future use. For maximum utilization of vitamin A in the body, there must be adequacy in the dietary intake of proteins and vitamin E. Vitamin A is almost colourless, fat soluble and sensitive to heat. Exposure to light may destroy vitamin A. Storage of vitamin A is associated with fatty acid most especially palmitic acid.

Functions of Vitamin A

i. Vision: vitamin A is used for the maintenance of the visual pupil for vision in dim light. In other words it prevents night blindness.
ii. Growth: vitamin A plays an important role in the development and maintenance of epithelial tissue and the development of bones.
iii. Reproduction: retinol or its aldehyde derivative (retinaldehyde) is necessary for normal reproduction in rat. Absence of vitamin A causes failure in spermatogenesis (manufacturing of sperm) in male and feotal resorption in female.
iv. Vitamin A plays a role in the release of proteolytic enzymes from particles in the lysosomes.
v. Vitamin A is involved in the stability of cell membrane.
vi. Deficiency of vitamin A has been found to cause changes which results in loss of appetite.

Food Sources of Vitamin A

Vitamin A is found in fruits and vegetables such as spinach, carrot, asparagus, peas, cabbage, papaya, watermelon, oranges, banana, and pineapple. They are also found in diary products such as milk, cheese, butter and margarine. They are also found in fish, meat, poultry and eggs such as liver, beef, lamb, chicken, calf, pork, egg yolk and whole egg. Vitamin A is present in the fat in milk and in form of precursor in fruits and vegetables. It is also available in only animal product which the carotene in their foods has been metabolized into vitamin A and the liver of such animal is the storage site of Vitamin A.

Deficiency of Vitamin A

a. Night blindness
b. Changes in the eye with the cornea first affected
c. Respiratory infections
d. Changes on skin with the development of folliculosis (small bumps) near the base of hair follicle that subsequently becomes keratinized
e. Changes in gastro-intestinal tract resulting into disturbances such as diarrhea.
f. Failure of teeth enamel in which the enamel in the teeth disappears as a result of deprivation in vitamin A.
g. There could be loss of sense of smell and taste.

Toxicity in Vitamin A
This is also known as hypervitaminosis of vitamin A and it results in the decreased stability of the membrane structure. It can cause the fragility of bones and also result in increase of calcium in both urine and blood therefore, resulting in low amount of calcium laid down in the bones.

Recommended Allowances for Vitamin A
The recommended allowances for vitamin A have been given as 5000 IU for an adult male per day, 4000 IU for women per day, 5000 IU for pregnant women per day and 6000 IU for a lactating mother per day. The need of vitamin A has been found to vary under different conditions. Performing tiring work in hot weather tends to increase the need for vitamin A.
After removal of the gall bladder in hypothyros m and when there is impairment of intestinal absorption of vitamin A, there is a need of increase in dietary intake of vitamin A.

2.6.3.2 Vitamin D

It exists as a cholecalciferol, vitamin D3, in animal sources and' ergosterol, vitamin Di, from vegetable sources. Before it was known as sunshine vitamin and rickets preventive factor since it could be used to prevent or cure infants of rickets; if the infants are exposed to sunlight or if they receive their vitamin D from cod-liver oil. Rickets is the condition that is characterized by defective bone formation in which there is inadequate deposition of calcium and phosphorous in the bone.
This results in deformity in the bones of the leg leading to bowing of legs and knock-knees. Rickets is primarily associated with children. The term "adult rickets" that is Ostem-Wilda results in the defect in the bone formation but not necessarily as a result of vitamin D deficiency.

Functions of Vitamin D

It is very useful in the metabolism of calcium as it is associated with the calcification of bones. It also acts to raise the blood calcium levels by facilitating the resorption of bones.
It is also involved in the metabolism of phosphorous as failure in calcification of bone is often caused by insufficient supply of phosphates. It has been found that the addition of vitamin D to the diet causes an increase in the rate of absorption of phosphates. Vitamin D, has been found to influence the rate of resorption of amino acid in the kidney tubules.

There is also an antagonistic relationship between vitamin D and hydrocortisone, a hormone of the adrenal gland. Hydrocortisone can suppress the high blood level of calcium that is associated with the excessive intake of vitamin D.

Sources of Vitamin D

Vitamin D is produced majorly by the exposure of the adipose tissue to ultraviolet rays in sunlight. Food sources also provide some relatively small amount of vitamin D. Margarine enriched with vitamin D and egg yolk are important sources of vitamin D. Other sources of vitamin D are fatty fish, butter, dietary supplement in form of fish liver oil fortified in infant food.

2.6.3.3 Vitamin E

Requirements of Vitamin E

For pregnant and lactating mothers the requirements has been set as 15 IU. The recommended intake of vitamin E for adult male has been put at 15 IU per day and for adult female it has been put at 12 IU per day.

Source of Vitamin E

Vitamin E is found mostly in vegetable oils, wheat, and oil. Normal cooking causes little destruction of vitamin E. Fruits and vegetables are relatively poor sources of vitamin E

2.6.3.4 Vitamin K

Vitamin K, also called Anti-hemorrhagic factor, belongs to the substance known as Quinones. Vitamin K is involved in the synthesis of blood clotting factor.
Vitamin K is derived from green and yellow vegetables and from its synthesis in the body by intestinal vertebra. Prolonged coagulation time

and frequent incidence of hemorrhage are the few symptoms of vitamin K deficiency.

2.6.4 Water Soluble Vitamins

2.6.4.1 Thiamin (B)

Thiamin occurs in the body mostly as thiamin hydrochloride, a white crystalline water soluble substance that is easily destroyed by heat or oxidation in the presence of alkaline.

Functions of Thiantin

Thiamin is part of the co-enzyme thiamin-pyrophosphate or thiamin diphosphate which is required for the metabolism of carbohydrate. Rice enriched with thiamin has been found to eliminate the incidence of beriberi.

Food Sources of Thiamin

Thiamin is found in cereal product providing about one-third of dietary thiamin. Meat, fish and poultry provide a fourth and dairy products a tenth of the available dietary' thiamin. Food sources of thiamin are yeast, pears, pork, orange drink, whole wheat bread, macaroni and wheat bread.

Deficiency of Thiamin

The deficiency is caused by low dietary intake of thiamin and caloric intake in the diet. Deficiency of thiamin results into loss of appetite or anorexia, decrease muscle tonus, mental depression and confusion, nystagnus caused by weakness of the cranial nerve, beriberi and growth retardation in animal.

Requirements of Thiamin

There is always a relationship between the caloric intakes for the thiamin need for all ages. The need for thiamin per day varies from 0.5 to 0.9mg in children. For boys, girls, men and women 1.2mg, 1.0mg, I.2mg, and 0.9mg of thiamin per day are recommended respectively.

2.6.4.2 Riboflavin

Riboflavin, known as vitamin B1 is essential for growth and repair of tissues in all animals. It is relatively resistant to effect of acid, heat and oxidation. Losses of riboflavin in food can be due to ultra violet or physical rays of sunlight on the food.

Functions of Riboflavin

Riboflavin has been found to the part of several enzymes and co-enzymes that are involved in a number of metabolic activities in the body.

Food Sources of Riboflavin

Milk is the most significant source of riboflavin. It is also found in the kidney, beef, liver, egg, and asparagus. The recommended intake of riboflavin is based on caloric intake, set as 0.55mg per 100Kcal and during pregnancy additional allowance of 3mg is made and during lactation additional allowance of 5mg is also made per day.

2.6.4.3 Ascorbic Acid (Vitamin C)

Vitamin C is closely related to monosaccharides and is stable to acid but easily destroyed by oxidation, alkali and heat. It has a molecular formula of $C_6H_8O_6$ which can undergo oxidation to dehydroascorbic acid ($C_6H_6O_6$). Ascorbic acid plays a growth promoting function. Ascorbic acid sulphate also has anti-scorbutic properties of Ascorbic acid. Animals that have the ability to synthesize vitamin C require no dietary intake of vitamin C and in this process, glucose or galactose is converted to Ascorbic acid. Human beings, guinea pigs and some bats rely on dietary supply of vitamin C for their vitamin C requirement since they lack the enzymes to synthesize vitamin C. During ripening process in plants, there is the accumulation of vitamin C.

Food Sources of Vitamin C

Vitamin C is found mostly from food of plants origin and except liver, no animal source supplies significant amount of vitamin C. Citrus fruits and their juices, tomatoes and cabbage supply significant amounts of vitamin C. During processing of foods containing vitamin C care must be taken to prevent loss of vitamin C through leaching and destruction by heat.

Functions of Vitamin C

a. Vitamin C is necessary for the normal oxidation of large amounts of tyrosine.

b. Vitamin C is essential for collagen formation.

c. Ascorbic acid has been implicated in the changes in tooth structure during the critical stage of tooth formation.

d. Vitamin C in the intestinal tract facilitates the absorption of iron and calcium.

e. The conversion of the inactive form of folic acid (a vitamin B group) to the active form is catalyzed by ascorbic acid.

Deficiency of Vitamin C

Deficiency of vitamin C leads to scurvy in children and young people more than in adults.

Vitamin C Deficiency also result in the weakness, irritability, loss of weight, pains in muscles or joints and gum bleeding. In deficiency of vitamin C wounds do not heal easily and there is reduced ability to resist generalized infection.

Requirements of Vitamin C

There is no hypervitaminosis of vitamin C as we have in vitamins A and D. The requirements of vitamin C vary from 35mg/day in infant to 45mg/day on adults. For pregnant and lactating mothers 60mg and 80mg are recommended the daily dietary allowances.

Self- Assessment Exercises 4

1. What are the food sources of vitamin A
2. State the functions of Vitamin C

2.7 LIPIDS

2.7.1 Nature, Composition and Physical Properties of Lipids

A number of oils and fats are visible example butter, margarine, vegetable oils, salad oils and fats surrounding meat. Some other oils and fats are finely dispersed in egg yolk and homogenized milk while some oils are marbled in meat fibres and in nuts.

Lipids consist of carbon, hydrogen and oxygen atoms just like carbohydrates. Phospholipids contain phosphate and nitrogen containing and some others contain phosphate and carbohydrate- like substances in addition to carbon, hydrogen and oxygen atoms. In lipids, the ratio of oxygen to carbon and hydrogen range from 1:7 to 1:3 unlike carbohydrate where the ratio is 1:2 of energy.

Every fat has a molecule of glycerol as shown below

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H-C-OH
   I
H-C-OH
   I
H-C-OH
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A molecule of glycerol has three hydroxyl (OH) groups and is common to all dietary lipids.

The fatty acids with even number of carbon atoms ranging from 4-22 carbon atoms combine with the glycerol to form monoglyceride, diglyceride or triglyceride depending on the numbers of fatty acids that react with the glycerol.

Monoglyccride fat has one fatty acids linked with the glycerol and diglyceride have two fatty acids linked with the glycerol. Most of the fats are triglyceride with three fatty acids linked with the glycerol. When the fatty acids connected with glycerol are not the same, we have mixed glycerides either diglycerides or triglycerides.

The fatty acids have the molecule formula of RCOOH, where R represents the hydrocarbon chain. The carboxylic groups of the fatty acids react with the hydroxyl group of the glycerol to form fat (an ester) - a reaction known as esterification.

The properties of Fats and Oils are determined by the:

i. Length of chain of the hydrocarbon group of fatty acids
ii. The degree of unsaturation of the hydrocarbon chain
iii. The types of fatty acids that react with the glycerol to form the fats and oil
iv. The order of the fatty acids that is attached to the glycerol.
Most of the food fats contain about eight to ten fatty acids in which some of them are saturated and some unsaturated.

A saturated fatty acid does not possess double bonds between any of its carbon atoms. Monounsaturated fatty acid has only one double bond, and if there is more than one double bond, then it is polyunsaturated fatty acid.

Fats with unsaturated fatty acids are liquid (oil) at room temperature with low melting point while those with saturated fatty acids have high melting point and they are solid at room temperature. The proportions of unsaturated to saturated fatty acids in fats and oils is called P/S ratio. The higher this ratio, the more unsaturated fatty acids are present in the fat and the more likely is for the fat to be in liquid form. Generally animal fats are higher in saturated fatty acids than vegetable fats. The few exceptions are only the chicken and fish fats with high P/S ratio.
The length of the hydrocarbon chain in these fatty acids also affects the property of the fats. Fats with short chain fatty acids are likely to be liquid while those ones with long chain fatty acids especially those with saturated chain are likely to be solid. Coconut oil, with large proportion of short chain fatty acids is liquid at room temperature.

The fatty acids in the fats and oils react with iodine in the proportion to the number of the double bonds in the fat. The reaction of the fats and oils with iodine is used to determine the degree of unsaturation of the fats and oils. The result obtained is called iodine value. The higher the iodine values of the reaction between iodine and a lipid, the greater the degree of unsaturation.

The degree of unsaturation in a lipid has implication for the deteriorative tendency of the fat. If the fat contains large proportion of unsaturated fatty acids, the double bonds to form peroxides which give off flavours in some fats.

2.7.2 Functions of Lipids in Diet

a. Source of Energy: Fat yields of 9 kilocalories of energy per gram of fat. This is more than 4 kilocalories that are yielded by the same weight of protein and carbohydrate. Animals store excess energy in form of fat. The fat is deposited in the adipose tissue of the body.

b. Satiety value: Fat has high satiety value since it takes time before it leaves the stomach. The slow rate at which fats leave the stomach delays the onset of hunger and this contributes to a feeling of satiety after a meal containing fat.

c. Carrier of fat soluble vitamins: Some vitamins that are fat soluble are vitamins A, D, E, and K. The elimination of fat from diet reduces the intake of these fat soluble vitamins.

d. Source of essential fatty acids: Fats are the sources of the essential fatty acids which play important biological roles as growth and anti-dermatitis factors. The essential fatty acids are linoleic acid, arachidonic and linoleic acids.

e. Precursors of prostaglandins: Prostaglandins are substances which stimulate the contraction of smooth muscles in the walls of blood vessels are synthesized from 20-carbon fatty acids. Lipids are precursors of these important substances.

f. Palatability: Fats contribute to the palatability of our diet and this is very noticeable when fat is used to fry food as a spread, as a base for salad dressing and as a flavour adjusts for vegetable. **g. Body Regulator:** Fat helps in regulating the uptake and excretion of nutrients by the cell.

h. Insulator: The fat underneath the skin serves as insulation material for the body. It protects the body against shock from changes in environmental climate. The fat layer should not be too thick, so as not to slow down the rate of the heat loss during hot weather. The very thick layer can also slow down physical movement.

i. Protector of vital body organs: The fat deposits around certain vital organs such as kidneys hold these organs in position and protect them from physical shock.

2.7.3 Dietary Requirements of Lipids

The body required the dietary source of linoleic acid and a diet that provides 2% of its calories from linoleic acid will meet the requirement for lipids. Nutritionists have suggested that the provision of 25 - 30% of calories from fat intake is for good health. The intake of fats that provide more than these values of calories can be injurious to body in view of the prevalence of the cardiovascular diseases resulting from the adverse effects of high fat intake in the diet.

Self- Assessment Exercises 5

1. What are the parameters that determine the properties of fats and oils
2. Why is fat said to be an insulator

2.8 Summary

This unit discusses Carbohydrates, Protein, Minerals, Vitamins and lipids under the following headings: Nature, Composition and Physical Properties, Food sources, Functions of the food class in Diet, Roles of the food class in the body, and Dietary requirements of the food class.

The classes of carbohydrates as monosaccharides, disaccharides and polysaccharides and the functions of carbohydrates are given as a source of energy, a dietary essential and as precursors of some important compounds such as nucleic acids in the body. The sources of carbohydrate are cereals, roots, tubers, concentrated sweets, fruits and vegetables. This unit explains that carbohydrates are inexpensive to demand and they constitute about 90 percent of the energy source in the diets of poor people of the world. This unit also discusses the need to supply dietary carbohydrate in order to spare protein of the process of gluconeogenesis that destroys proteins and converts some amino acids to glycogen so that the protein could perform more useful functions of growth and maintenance of body tissues.

Minerals have been found to be important constituents of the body's hard and soft tissues and regulator of some body functions. Macro-elements have been found to be those consumed in more than 0.005% of the body weight while microelements are those present in less than 0.005% of the body weight. Though, minerals are consumed in relatively small amount, their deficiencies could lead to serious health problems.

The vitamins are classified as fat soluble and water soluble. The fat soluble vitamins are vitamins A, D, E and K. There are eleven water soluble vitamins are grouped into - vitamin C and the vitamins B group. The B-group vitamins are given as thiamin (B), inositol, choline, Riboflavin (B1), pantothenic acid, Biotin, Pyridoxine (B6), Niacin (B3), Folic acid and cobalmin (B12). There is no toxic effect of excessive consumption of most vitamins except those of vitamins A and D.

The composition, sources, functions, dietary requirements, denaturation, and determinants of the quality of proteins were discussed in this unit. Properties of protein are dependent on the types of amino acids in the protein, also determined are the three dimensional configuration of protein that determines both the enzymatic and catalytic activities of the protein. Heat vigorous agitations, presence of salts of heavy metals, excessive alkalinity and acidity, presence of alkaloidal agents and alcohol could lead to the changes in this three dimensional configuration of protein, thereby causing Denaturation of protein. Animal proteins have been found to have higher quality in terms of digestibility and amino acids contents than vegetable proteins. The quality of protein and the completeness of other wise of protein are determined by the number and amount of the essential amino acids in the proteins

Fats are synthesized from glycerol and fatty acids. The length of the carbon chains of the fatty acids, the level of saturation of the fatty acid, the type of the fatty acid and their order determines the properties of the lipids. Liquid oils at room temperature consist more of unsaturated fatty acids and short chain fatty acids. Fats and oils are useful in the diets and in the body. Fats serve as a rich source of energy, a body regulator, insulator in the body and precursors of prostaglandins. They also have high satiety value and improve the palatability of diets.

2.9 References

Lake, B and Inlaternurte, M. (1980) Food and Nutrition 13th edition, Mills and Boon Ltd., London.

Hutkins, R (2006). Microbiology and Technology of Fermented Foods – A Modern Approach. Blackwell Publishing Professional, 488 pages

International Commission for Microbiological Specifications of Foods (ICMSF) (1996). Microorganisms in Foods - Characteristics of Microbial Pathogens – Springer. 1996. 524 pages

Jay, J.M., Loessner, M.J. and Golden, D.A (2005). Modern Food Microbiology, 7th edition, Springer food science text series, 790 pages

2.10 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. Roots and tubers like Yams, potatoes, cocoyam are rich sources of carbohydrate.

Legumes are also good sources of carbohydrates. Ripe fruits and sugars, syrups, molasses, jams and jellies, beverages, candies and honey are good sources of carbohydrates.

2. Monosaccharides, Disaccharides and Polysaccharides

Answers to Self-Assessment Exercises 2

1. Essential Amino Acids are Leusine, isoleucine, lysine, methionine, phenyalanine, threoneine, tryptophan, valine and histidine.

2. i. Promoting growth and maintenance of the body tissues

ii. Formation of essential compounds in the body

iii. Maintenance of body neutrality

iv. Stimulation of antibody production

v. Transportation of nutrients

Answers to Self-Assessment Exercises 3

1. a. Constituents of the body tissues
b. Regulators of some body functions
2. Iron, iodine, zinc, selenium, manganese, copper, fluorine, chromium, cobalt and molybdenum.

Answers to Self-Assessment Exercises 4

1. Vitamin A is found in fruits and vegetables such as spinach, carrot, asparagus, peas, cabbage, papaya, watermelon, oranges, banana, and pineapple. They are also found in diary products such as milk, cheese, butter and margarine. They are also found in fish, meat, poultry and eggs such as liver, beef, lamb, chicken, calf, pork, egg yolk and whole egg. Vitamin A is present in the fat in milk and in form of precursor in fruits and vegetables. It is also available in only animal product which the carotene in their foods has been metabolized into vitamin A and the liver of such animal is the storage site of Vitamin A.

2. Functions of Vitamin C

a. Vitamin C is necessary for the normal oxidation of large amounts of tyrosine.
b. Vitamin C is essential for collagen formation.
c. Ascorbic acid has been implicated in the changes in tooth structure during the critical stage of tooth formation.
d. Vitamin C in the intestinal tract facilitates the absorption of iron and calcium.
e. The conversion of the inactive form of folic acid (a vitamin B group) to the active form is catalyzed by ascorbic acid.

Answers to Self-Assessment Exercises 5

1. The properties of Fats and Oils are determined by the:
v. Length of chain of the hydrocarbon group of fatty acids
vi. The degree of unsaturation of the hydrocarbon chain
vii. The types of fatty acids that react with the glycerol to form the fats and oil
viii. The order of the fatty acids that is attached to the glycerol.

2. The fat underneath the skin serves as insulation material for the body. It protects the body against shock from changes in environmental climate. The fat layer should not be too thick, so as not to slow down the rate of the heat loss during hot weather. The very thick layer can also slow down physical movement.

UNIT 3 FOOD COMPOSITION AND ITS FUNCTIONS

CONTENTS

3.1 INTRODUCTION

Humans consume the following foods: Cereals, and Cereal Products, Starchy roots and tubers. Legumes, leafy vegetables, fruits, nuts and seeds, sugars, syrups, sweets and preserves, meat, poultry and other meat products, sea food, shell fish, eggs, and roe, milk, cream and cheese, fats and oils, herbs and spices, non-alcoholic and non-dairy beverages, alcoholic beverages, dietetic preparations, salt, etc.

3.2 Learning Outcomes

By the end of this unit, you will be able to:

- Write the major and minor constituents of food
- Analyse the functions of each food major group
- Discuss the structure of the food major groups

3.3 Food Composition

3.3.1 Proteins

Proteins are large molecules with widely varied properties and many different functions. Proteins consist of amino acids linked together by peptide bonds. Haemoglobin - a red blood cell protein is involved in the transportion of oxygen. Enzymes are proteins that catalyse the chemical reactions of cells. Collagen is a major structural protein in bones, tendons and skin. Antibodies, which are critical components of the immune system, and crystallins, found in the lens of the eye, are proteins. Some hormones are proteins. The main functions of protein are: to build body tissue, regulate functions such as muscle contraction and blood pressure, synthesize enzymes and some hormones (such as insulin) and other complex substances that govern body processes.

Structure and Composition of Proteins

The name of the acids comes from the stem word “amine” meaning "derived from ammonia." There are about 20 common amino acids in most proteins. The amino acids join together in long chains, the amino group (- NH-) of one amino acid link with the carboxyl group (-COO-) of another. The linkage is known as a peptide bond (-$COONH_2$) and a chain of amino acids is known as a polypeptide. The amino acids differ in structure and properties as a result of diiference in the content and size of side chain; each has an amino group, a carboxylic acid group and an alkyl side chain (-R). Some amino acid side chain are composed of only carbon and hydrogen atoms and are hydrophobic (water hating) and some contain oxygen and nitrogen atoms and are hydrophilic (water loving); some ionise and have positive or negative electrostatic charges. Each protein has a specific number and sequence of amino acids, where peptide bonds connect the amino group of one to the carboxyl group of the next. The resulting linear sequences give each protein a specific size, a unique three-dimensional structure and in one way or another, account for its properties.

Protein and Nutrition

Plants, bacteria and most other microorganisms synthesize all of the amino acids required for protein synthesis but humans and most other animals, cannot synthesize all of the amino acids and must obtain some of them from their diet. Eight of the 20 amino acids that make up protein, are considered essential because the body cannot synthesize them, but must be supplied ready-made in foods. When any of the essential amino acids is lacking, the remaining ones are converted into energy-yielding compounds, resulting in the excretion of its nitrogen. When excess protein is eaten, which is often the case in countries with heavy meat diets, the extra protein is similarly broken down into energy-yielding compounds. Because protein is by far scarcer than carbohydrates and yields the same 4 calories per gram, the eating of meat beyond the tissue-building demands of the body becomes a wasteful way of procuring energy. Foods from animal sources contain complete proteins because they include all the essential amino acids. In most diets, a combination of plant and animal protein is recommended 0.8 grams per kg of body weight is considered a safe daily allowance for normal adults.

Increased risks of gout, certain cancers and heart disease have been correlated with high protein diets. Kwashiorkor, a protein-deficiency disease that primarily affects children 1 to 4 years old who are weaned on starchy foods, is still endemic to parts of Africa, Asia, and South America.

3.3.2 Fats

Fats or lipids are a family of chemical compounds stored by plants and animals as a source of energy. In most animals, fats are stored in special cells that tend to form pads of tissue under the skin and around certain organs and joints, the locations depending on the species. Stored fat, or

adipose tissue, serves as a fuel reserve for metabolism. Fat protects the body from shocks, joints and provides insulation. In plants, fats in the form of oil are found in the stems, seeds and fruit.
Fat is a concentrated source of energy and produce more than twice the energy produced by equal amounts of carbohydrates and proteins. Being a compact fuel, fat is efficiently stored in the body for later use when carbohydrates are in short supply. Animals obviously need stored fat to hide them over dry or cold seasons, as do humans during times of scarce food supply. All fats are made up of units of glycerol and fatty acids and the nature of fatty acids eaten can affect a person's health. Saturated fatty acids found in butter, milk and other animal products can raise the level of cholesterol in the blood, thus leading to arteriosclerosis but unsaturated fats found in vegetable oils can reduce high levels of blood cholesterol.

The body's adipose tissue is in a constant state of build-up and breakdown, thus ensuring a continual supply of fatty acids. Fatty acids containing as many hydrogen atoms as possible on the carbon chain are called saturated fatty acids and are derived mostly from animal sources. Unsaturated fatty acids are those that have some of the hydrogen atoms missing; this group includes monounsaturated fatty acids, which have a single pair of hydrogen missing, and polyunsaturated fatty acids (found mostly in seed oils), which have more than one pair missing. Saturated fats in the bloodstream have been found to raise the level of cholesterol, and polyunsaturated fat tends to lower it. Saturated fats are generally solid at room temperature; polyunsaturated fats are liquid.

The predominant substances in fats and oils are triglycerides, chemical compounds containing any three fatty acids combined with a molecule of glycerol. The fatty acids consist of a chain of carbon atoms with a carboxylic acid group (-COOH) at one end. The number of carbon atoms ranges from four to more than 22, but the most common chain length is 16 or 18. Because they are synthesized in the body from two-carbon units (acetyl coenzyme A), chain lengths are nearly always even numbers. Butyric acid is an example of a saturated fatty acid.

Fats with a high percentage of saturated fatty acids tend to be solid at room temperature; e.g. butter and lard. Those with a high percentage of unsaturated fatty acids are usually liquid oils; e.g. sunflower, safflower and corn oils. In the shorthand notation for fatty acids, the number to the left of the colon is the number of carbon atoms, while the number to the right of the colon represents the number of double bonds; e.g. 4:0 has four carbon atoms and no double bonds (i.e. saturated). This is the shorthand notation for butyric acid.

A small group of fatty acids are essential in the diet. They occur in body structures, especially the different membranes inside and around cells, and cannot be synthesized in the body from other fats. Linoleic acid (18:2) is the most important of these fatty acids because it is convertible to the other essential fatty acids. Linoleic acid has two double bonds and is a polyunsaturated fatty acid. Linoleic acid is an essential fatty acid which tends to lower the plasma cholesterol. Linoleic acid occurs in moderate to high proportions in many of the seed oils; e.g. corn, sunflower, cottonseed and safflower oils. Edible fats and oils contain smaller amounts of other lipids as well as triglycerides.

3.3.3 Carbohydrates

Carbohydrates (cellulose, starches, sugars and many other compounds), are the most abundant single class of organic substances found in nature. They are formed in green plants by a process known as photosynthesis, in which energy derived from sunlight is used for the assimilation of carbon dioxide from the air. The most common naturally occurring sugars are the aldohexoses, which have six carbon atoms and four asymmetric centres. Aldohexoses include glucose, mannose, galactose and the fruit sugar fructose. The aldopentose sugars ribose and deoxyribose (having 5 carbon atoms) are important constituents of nucleic acids.

Disaccharides and polysaccharides are formed from two or more monosaccharides joined by chemical bonds. Glucose linked to fructose, forms the disaccharide sucrose (cane sugar); glucose linked to galactose forms the disaccharide lactose (milk sugar); glucose linked to glucose forms the disaccharide maltose. Starch, glycogen and cellulose are all chains of glucose units, differing only in their modes of bonding and degree of chain branching. Some biologically important sugar derivatives are sugar alcohols, sugar acids, deoxy sugars, amino sugars, sugar phosphates, muramic, and neuraminic acids. Plants store starch in roots, tubers and leafy parts mainly during photosynthetic activity; some plants, such as sugar beets and sugarcane, also store sucrose.

Carbohydrates function as the main structural elements and storage products of energy in plants. The principal forms are starch in plants and glycogen in animal tissues. These are polymers of glucose; they are deposited in cells in the form of granules when a surplus of glucose is available. The polymers are broken down to release energy during metabolism.

Carbohydrates and Nutrition

Carbohydrates are the most abundant food sources of energy and occur in the form of starches and sugars. Starches are found mainly in grains, legumes and pulses, roots and tubers and some rhizomes, while sugars are found in plants and fruits. The carbohydrates containing the most nutrients are the complex carbohydrates, such as unrefined grains, tubers, vegetables and fruits, which also provide protein, vitamins, minerals and fats. Other beneficial sources are foods made from refined sugar, such as confectionery and soft drinks, which are high in calories but low in nutrients and fill the body with what nutritionists call empty calories.

A large part of the human diet consists of carbohydrates in the form of starch and sucrose which must first be broken down to their component sugars by digestive enzymes before absorption into the bloodstream. In humans cells use carbohydrates in the form of glucose - the body's main fuel. After absorption from the small intestine, glucose is processed in the liver, which stores some as glycogen and passes the rest into the bloodstream. In combination with fatty acids, glucose forms triglycerides – fat compounds that can easily be broken down into combustible ketones. Glucose and triglycerides are carried by the bloodstream to the muscles and organs to be oxidized. Excess quantities are stored as fat in the adipose and other tissues for later use.

3.3.4 Water

Water also known as moisture is the predominant constituent of many foods. As a medium, water supports chemical reactions and it is a direct reactant in hydrolytic processes. The removal of water from food or binding it by increasing the concentration of common salt or sugar retards many reactions and inhibits the growth of microorganisms, thus improving the shelf life of a number of foods. Through physical interaction with proteins, polysaccharides, lipids and salts, water contributes significantly to the texture of food.

Water is of particular importance in the food industry as it is used for varied purposes and it is not possible to function properly in a place without water; hence, measures should be taken to ensure that the quality of water is always potable, especially in the industries where water is used as a food component. Even though water is utilized in the food industry for different purposes, the most significant uses are in product ingredient, formulation and preparation. The highest quantity of water is used by the poultry, meat and milk industries. Soft and alcoholic beverages, starch and processed agricultural products (fruits and vegetables) are high water users while cereal milling and baking industries are the low water-consuming branch of the food sector. The water used as a food ingredient, cleaning agent and/or any contact with food must be of potable quality.

Water performs the essential function of absorbing nutrients from our food. It also helps in releasing waste from our body in form of sweat and urine. The function of water is better understood when its structure and its state in a food system are clarified.

Structure of water molecule

The six valence electrons of oxygen in a water molecule are hybridized to four sp^3 orbitals that are elongated to the corners of a somewhat deformed, imaginary tetrahedron. The two hybrid orbitals form O–H covalent bonds with a bond angle of 105° for H–O–H, whereas the other 2 orbitals hold the nonbonding electron pairs (n-electrons). The O–H covalent bonds, due to the highly electronegative oxygen, have a partial ionic character. Each water molecule is tetrahedrally coordinated with four other water molecules through hydrogen bonds. The two unshared electron pairs (n-electrons or sp^3 orbitals) of oxygen act as H-bond acceptor sites and the H–O bonding orbitals act as hydrogen bond donor sites. The dissociation energy of this hydrogen bond is about 25 $kJmole^{-1}$. The simultaneous presence of two acceptor sites and two donor sites in water permits association in a three-dimensional network stabilized by H-bridges.

The Use and Effect of Water Characteristics in Food Production

The most important parameters of water are the mineral content, hardness and pH. While water affects the characteristics of the food by interacting with various components of the food at the molecular level, its composition and properties also change. Major components of food such as carbohydrates, proteins, some vitamins and minerals are water-soluble. Proteins and carbohydrates such as starch start to plasticise using water. As an ingredient, water may alter the rheological properties of dough and the bakery products by affecting gluten structure, the sensory traits of coffee due to the changes in the extraction capacity, the physical and chemical properties of grain products during cooking. Water is the second most important ingredient after the characteristic ingredient of food and in terms of quantity; it is the major one in many foods. Water as a great solvent, has numerous substantial functions and interacts with other components of food through hydrogen bonds and hydrophilic and hydrophobic interactions which change the attributes of the food and water itself. The roles of water in food science, processing and engineering are of vital importance and generally, it affects food quality directly. Water is used for formulation and dilution of both soft and alcoholic beverages and food products, a cooking medium for vegetables and cereals and a reaction medium for dough preparation. Apart from these, water is also used to modify the texture, taste, reactions and physical properties of foods. For instance, the gluten structure is formed after the mixing of the flour with the water. Most of the major (carbohydrates and proteins) and minor (minerals, vitamins and acids) food constituents are soluble or mixable in water. Mineral composition, hardness and pH of the water are of particular significance in the food industry because they have considerable influence on the quality attributes of the food products.

The chemical properties of water have vital importance on the final properties of a variety of foodstuffs. Among the chemical properties of water, hardness is the most critical factor as water may contain half of the elements in the periodic table, some in great amount and others in lower concentrations. Water can be categorized as acidic, neutral and alkaline in point of pH. The hardness of water is related to the presence and concentration of divalent metal cations like calcium, magnesium and a little from iron and manganese. The hardness of water can be classified into two categories: temporary and permanent hardness. Permanent hardness is caused by the ions of sulphate, chloride and nitrates in the water while temporary hardness is originated from the carbonates and bicarbonates of calcium and magnesium.

Forms of Water in Foods

The three states of water in food products are:

1. Free water: This water retains its physical properties and thus acts as the dispersing agent for colloids and the solvent for salts.

2. Adsorbed water: This water is held tightly or is occluded in cell walls or protoplasm and is held tightly to proteins.

3. Water of hydration: This water is bound chemically, for example, lactose monohydrate; also some salts such as $Na_2SO_4 \cdot 10H_2O$.

Depending on the form of the water present in a food, the method used for determining moisture may measure more or less of the moisture present.

3.3.5 Fibre

Fibre is the remnants of plant cells resistant to hydrolysis (digestion) by the alimentary enzymes of man. It may be digested or form the substrate for fermentation by gut microbiota, either complete or partial. Human gut enzymes can break down only α-glucoside bonds, but fibre polysaccharides contain non-α linkages. Dietary fibre includes cellulose and hemicellulose, lignin, oligosaccharides, gums, waxes, mucilages and pectins, all of which fall into two categories: soluble and insoluble fibre.

Types of dietary fibre

Soluble fibre forms a gummy substance when added to water, and includes pectins, mucilages and gums. It can help to lower blood glucose levels and reduce fat absorption, as well as to lower the levels of cholesterol in the blood. Foods that provide adequate amounts of soluble fibre include oats, legumes, raw unpeeled apples, blueberries and nuts.

Insoluble fibre remains intact when in contact with water. It is useful in increasing gut motility, moving food through the intestine and preventing the stasis of toxins in the gut lumen. It also traps water, thus increasing stool volume and helping to soften and regularize stool movement. Foods that are rich in insoluble fibre include whole grains, such as whole wheat, brown rice, carrots, tomatoes and cucumbers, as well as legumes. Insoluble fibre includes cellulose and hemicellulose with lignins.

Sources of fibre

Various plant foods contain differing amounts of fibre, and the percentage also varies with the maturity and plant part. For instance, the content of cellulose is high in the following: root vegetables, leafy vegetables, legumes or pulses and certain fruits such as pears and apples Lignin content is high in strawberries and peaches, while pectins are found in high quantities in citrus fruits. Cereals and grains are rich in both cellulose and hemicellulose.

The functional properties of dietary fibre, including the water retention capacity (WRC), the swelling capacity (Sw), the fat retention capacity (FAC), antioxidant activity and prebiotic activity are associated with the physicochemical characteristics of cell wall polysaccharides, varying according to their composition. WRC, mainly related to insoluble dietary fibre (IDF), prevents and treats different intestinal disorders by increasing faecal bulk and reducing the gastrointestinal transit time. In food-technological terms, dietary fibre with high WRC can be used as a functional ingredient to avoid syneresis and to modify the viscosity and texture of some formulated foods, whereas dietary fibre with high FAC allows stabilisation of fat in emulsion-based products. Swelling capacity in the stomach and an increase in viscosity of the digesta are associated with soluble dietary fibre (SDF), which slows down the absorption of nutrients from the intestinal mucosa and lowers the postprandial blood glucose and insulin responses. The prebiotic effect of dietary fibre is probably the most important functional property. Dietary fibre reaches the colon, where it is fermented by the intestinal microbiota, generating short-chain fatty acids such as butyric, propionic, and acetic acids. These compounds are associated with a wide range of physiological properties, including the improvement of digestive tract disorders and anticancer activity.

3.3.5 Ash

Ash is the inorganic residue from the incineration of organic matter. The ash content is determined from the loss of weight which occurs during complete oxidation of the sample at a high temperature (500 to 600^{o}C) through volatilization of organic materials. The ash obtained is not necessarily of exactly the same composition as the mineral components present in the original food because there may be losses via volatilization or some interaction between constituents. For complete ashing, the heating is continued until the resultant ash is uniform in color, white or gray, occasionally green or reddish, and free from particles of unburned carbon and fused lumps. Ashing may be performed by incineration over an open flame, in a muffle furnace, in a closed system in the presence of oxygen, or by wet combustion in the presence of sulfuric acid, nitric acid, and perchloric acid alone or in mixtures. The determination of ash content is of value in the analysis of food for various reasons. The ash content can be regarded as a general measure of quality in certain foods such as tea, flour and edible gelatine, and often is a useful criterion in identifying the authenticity of a food. The ash analysis has been chiefly used for the determination of adulteration of certain foods. A high ash figure suggests the presence of an inorganic adulterant, and this condition is advisable to determine the acid-insoluble ash. The presence of large amounts of ash in finished products such as sugar, starch, gelatin, fruit acids, or pectin is objectionable. The ashing of vegetable and plant materials, particularly cut sections, is recognized as a useful tool in determining the nature and distribution of mineral constituents of plants. The ash content is an index of the quality of feed stuffs used for poultry and cattle. The ash content serves as a reliable index of the metabolism of yeast. The total ash content is a useful parameter of the nutritional value of many foods and feeds. It is helpful with many foods to quantify not only the total ash but also the ash soluble and insoluble in water, the alkalinity of the soluble ash and of the total ash, and the proportion of ash insoluble in acids. High levels of acid-insoluble ash indicate the presence of sand or dirt in food.

3.4 SUMMARY

This unit discussed the major food composition to include proteins, Fats and Carbohydrates. It also consists of minor but essential nutrients such as vitamins and minerals. Cereals, roots and tubers supply energy and vitamin B complex, legumes and leafy vegetables supply proteins and carotenoids or pro- vitamin A, while meat, fish and eggs supply proteins. Animal fats contain mainly saturated fatty acids, whereas vegetable oils contain poly-unsaturated fatty acids which are essential to humans.

Food compositions differs depending on the group that it belongs to: Cereals include Rice, Corn, Millet, Sorghum which supply fibre and low tryptophan needed for body buildup of Niacin. Polished rice is also low in thiamine. Legumes, Meat, and Milk supply high proteins but also legumes contain anti-nutrients. Fruits and vegetables contain 70% water but supply high vitamin C, Milk and milk products are rich in proteins.

Self- Assessment Exercises 1

1. Describe the constituents of Protein.

2. Explain saturated and unsaturated fats

3.5 References/Further Readings

Akan, S. and Bayram, M (2021). The Importance of Water Composition on Some Characteristics of Food Products. *International Conference on Innovative Engineering Applications*, (CIEA' 2021), 20-22

Walker, A.F (1990). Applied Human Nutrition. Aspen Publishers. 300 pages.

Belitz, H.D., Grosch, W., Schieberle, P and M.M. Burghaghen, M.M (2004). Food Chemistry. Springer, 1071 pages

Hutkins, R (2006). Microbiology and Technology of Fermented Foods – A Modern Approach. Blackwell Publishing Professional, 488 pages

International Commission for Microbiological Specifications of Foods (ICMSF) (1996). Microorganisms in Foods - Characteristics of Microbial Pathogens – Springer. 1996. 524 pages

Jay, J.M., Loessner, M.J. and Golden, D.A (2005). Modern Food Microbiology, 7th edition, Springer food science text series, 790 pages

Rivas, M.Á., Casquete, R., Córdoba, M.d.G., Ruíz-Moyano, S., Benito, M.J., Pérez-Nevado, F. and Martín, A (2021). Chemical Composition and Functional Properties of Dietary Fibre Concentrates from Winemaking By-Products: Skins, Stems and Lees. *Foods* 2021, 10, 1510. https://doi.org/ 10.3390/foods10071510

Park, Y.W. (1996). Determination of Moisture and Ash contents of Foods. Handbook of Food Analysis. Leo M.L. Nollet (ed). Marcel Dekker, Inc., New York, 59-92

3.6 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. Each protein has a specific number and sequence of amino acids, where peptide bonds connect the amino group of one to the carboxyl group of the next. There are about 20 common amino acids in most proteins. The amino acids join together in long chains, the amino group (- NH-) of one amino acid link with the carboxyl group (-COO-) of another. The linkage is known as a peptide bond (-$COONH_2$) and a chain of amino acids is known as a polypeptide. Some amino acid side chain are composed of only

carbon and hydrogen atoms and are hydrophobic (water hating) and some contain oxygen and nitrogen atoms and are hydrophilic (water loving); some ionise and have positive or negative electrostatic charges.

2. Unsaturated fatty acids are those that have some of the hydrogen atoms missing; this group includes monounsaturated fatty acids, which have a single pair of hydrogen missing, and polyunsaturated fatty acids (found mostly in seed oils), which have more than one pair missing.

   Saturated fats in the bloodstream have been found to raise the level of cholesterol, and polyunsaturated fat tends to lower it. Saturated fats are generally solid at room temperature; polyunsaturated fats are liquid.

UNIT 4 THE ROLE OF MINERALS IN HUMAN

CONTENTS

4.1 INTRODUCTION

Most elements are present in the average diet, the minerals may not always be ingested in quantities sufficient to satisfy metabolic needs, especially during growth, stress, trauma, blood loss and in some diseases. Minerals are classified as macro or trace depending on the body's requirements. Macro elements are: calcium, magnesium, chlorine, phosphorus, potassium, sulphur, sodium and potassium. Trace elements are other inorganic substances that appear in the body in minute amounts but are essential for good health. Little is known about how they function, and most knowledge about them comes from how their absence, especially in animals, affects health. Trace elements appear in sufficient amounts in most foods and they include chromium, copper, fluorine, iodine, iron, selenium and zinc.

4.2 Learning Outcomes

By the end of this unit, you will be able to:

- Write the macro and trace elements
- Discuss metabolic functions of each mineral element through the deficiency symptoms
- Write the dietary sources of these mineral elements
- Discuss the advantages of eating foods containing dietary fibre.

4.3 Macro Elements

4.3.1 Calcium

Body requirements for calcium are generally met by eating or drinking dairy products, especially milk and cheese as well as dried legumes and vegetables. Most calcium (about 90%) is stored in bone, with a constant exchange occurring among blood, tissue and bone. The intake is balanced by losses in urine and faeces. The blood levels of calcium and its intestinal absorption or deposition from bone are all controlled by a complex interplay of vitamin D, parathyroid hormone and calcitonin. Contrary to some long-held beliefs, high intakes of protein and phosphorus do not lead to a loss of calcium but excessive dietary fibre can hinder its absorption.

Calcium promotes bone rigidity and is important in maintaining the integrity of intracellular cement and cellular membranes. It also regulates nervous excitability, muscle contraction and may be protective against high blood pressure. Calcium intake should be increased during periods of growth, pregnancy and lactation. Diseases of calcium metabolism include vitamin D deficiency, hypervitaminosis D, hypo- and hyper-parathyroidism, and some forms of renal disease.

Calcium depletion is difficult to recognise because 99 percent of the calcium in the body is in the bones. Osteoporosis is a calcium deficiency disease manifested by reduced bone mass for a particular length or volume of bone. Osteoporosis is common in postmenopausal women in industrialized societies. It causes bone pain and a tendency to fractures. Multiple causes of Osteoporosis include lack of exercise as well as the possibility of insufficient dietary calcium.

4.3.2 Phosphorus

Phosphorus combined with calcium plays vital roles in bone and teeth formation, acid-base balance maintenance, haemostasis of calcium and in reactions involving carbohydrates, lipids and proteins. The chemical energy of the body is stored in "high energy phosphate" compounds called adenosine triphosphates (ATP's). Elemental phosphorus is extremely poisonous, but phosphorus ingested as phosphates in the diets like milk, cheese, yoghurt, fish, poultry, meats and grains, is not toxic. Deficiency of phosphorus is manifested in general body weakness and loss of calcium.

4.3.3 Magnesium

Magnesium is an essential element in human metabolism. It functions in the activities of muscles and nerves, enzyme activation, protein synthesis, maintaining the electrical potential in nerve and muscle cells and many other reactions. It is found mainly in whole grains and green leafy vegetables. Magnesium deficiency results in growth failure, behaviour problems and occasional spasms. Magnesium deficiency may also occur in cases of alcoholism, diabetes mellitus, pancreatitis and renal diseases. Prolonged deficiency of Magnesium can cause changes in heart and skeletal muscle. Excessive retention of magnesium can occur in renal disease and results in muscle weakness and hypertension. Magnesium deficiency among malnourished people, especially alcoholics, leads to tremor and convulsions.

4.3.4 Sodium

Sodium is present in small and usually sufficient quantities in most natural foods and is found in liberal amounts in salted prepared and cooked foods. It functions mainly in the maintenance of acid-base and body water balance, and nerve function regulation. Sodium depletion occurs usually with accompanying water loss, as a result of massive loss of fluids as in severe cases of diarrhoea, vomiting and excessive urination. Deficiency of Sodium results in muscle cramps, reduced appetite and mental apathy. Excess sodium causes oedema, an over accumulation of extra cellular fluid.

4.3.5 Potassium

Potassium occurs naturally in bananas, leafy vegetables, potatoes, milk and meats. Potassium functions mainly in maintenance of acid-base and fluid balance and nerve transmission. Depletion of Potasium occurs in situations similar to sodium and may become obvious if sodium and water are replaced. Potassium loss is likely to occur with diarrhoea or overuse of purgatives, with regular use of diuretic drugs (drugs causing increased urine output), with corticosteroid treatment. Deficiency of potasium results in muscle cramps, mental confusion, loss of appetite, and irregular cardiac rhythm.

Self- Assessment Exercises 1

1. What are trace elements?
2. List four macro elements.

4.4 Micro Elements

4.4.1 Iodine

Iodine is found naturally in salt-water fishes, shellfish, dairy products and vegetables. It is associated with the synthesis of thyroxine and the function of the thyroid gland. Persons living in coastal regions usually receive an adequate supply of iodine because of its high content in seafood. In geographical regions located far inland, lack of iodine in food is apt to occur, causing goitre, so a small amount of iodine is often added by manufacturers of table salt. Elemental iodine is highly poisonous, and its only used in medicine is as an antiseptic. High frequency of endemic goiter causes a birth defect known as cretinism, and a large percentage of apparently normal people develop abnormalities such as learning disabilities, deafness, a higher rate of stillbirths and malformed babies. Iodized salt and injection of two millilitres of iodized oil to all women of childbearing age are effective ways of preventing the abnormalities.

4.4.2 Iron

Iron is a vital component of haemoglobin and also of certain respiratory enzymes. The main function of iron is in the formation of haemoglobin, the red pigment of the blood that carries oxygen from the lungs to other tissues. Iron rich foods include meat (liver and heart), Lean meats, eggs, whole grains, wheat germ, legumes and most green vegetables. Iron requirement increases during the growth period, pregnancy, excessive menses and other instances of blood loss. An average diet containing 10 to 15 mg a day is adequate for most people. Iron deficiency resulting in anaemia, can be treated by large amounts of iron in order to gain positive absorption.

Iron deficiency is common globally and is more in women than in men. Bleeding depletes the body of iron because each millilitre of blood contains 0.5 mg of iron. When iron stores are empty, there is anaemia with small cells containing less haemoglobin than normal.

4.4.3 Zinc

Zinc is found mainly in lean meat, whole-grain breads and cereals, dried beans and seafood. Zinc serves as a cofactor of dehydrogenases and carbonic anhydrase. Zinc loss occurs during such stress situations as surgical operations and its replacement aids in wound healing.Dietary programmes often promote zinc loss, while the use of concentrated zinc supplements can lead to calcium deficiency. Zinc deficiency in humans includes: various combinations of loss of taste, retarded growth, delayed wound healing, baldness, pustular skin lesions, growth failure, small sex glands, impotence in males, infertility in females, delayed wound healing, mental lethargy and reduced immunity to infections. Depression, vomiting and headache are caused by over ingestion of zinc or inhalation of its vapour.

4.4.4 Fluorine

Fluorine is found in dental enamel and bones as fluoride and It functions in bone structure maintenance and increases the resistance of the enamel to deterioration by acid. The chronic toxic dose of fluoride starts at intakes of about 5 mg per day; the first sign is mottling of the teeth. Above 10 milligrams per day bony outgrowths may occur. The only foods that contain appreciable amounts of fluoride are tea and fish. In places where the drinking water is not fluorinated many obtain some fluoride from toothpastes, a few give fluoride tablets to children prophylactically, and dentists apply fluoride solution directly to their patients' teeth periodically. Fluoride deficiency results in osteoporosis and tooth decay.

4.4.5 Other micro elements

Selenium is found mainly in seafoods, meat and grains. It prevents breakdown of fats and other body chemicals. Its deficiency is manifested in various forms of anaemia.

Copper occurs naturally in meats and drinking water. It aids red blood cell formation. Deficiency of copper results in anaemia and impaired bone and nervous tissue development. Chromium occurs naturally in legumes, cereals, organ meats, fats, vegetable oils, meats and whole grains. It functions mainly in glucose metabolism. Chromium deficiency results in adult onset of diabetes.

4.5 Dietary Fibre

Dietary fibre also known as bulk and roughage, can be defined as food material, particularly plant material, that is not hydrolysed by enzymes secreted by the human digestive tract but may be digested by microflora in the gut.

It refers to the remains of plant cell walls, a complex mixture of carbohydrates that resist digestion in the intestinal tract and are therefore apparently of no nutritional value in the diet. Dietary fibre is essential in the diet even though it provides no nutrients. Human nutritionists have thus disregarded dietary fibre for many years.

The term non-starch polysaccharide is preferred to the less-precise term dietary fibre and it includes cellulose, hemicelluloses, pectins, fructans, gums and lignins. They are all polysaccharides except lignin, which occurs with cellulose in the structure of plants. The various types of non-starch polysaccharide (NSP) can be divided into two broad grups: those that are insoluble in water (celluloses, some hemicelluloses and lignin) and those that are soluble in water (beta-glucans, pectins, gums, mucilages and some hemicelluloses), forming viscous gels. However, the Codex definition recognises that there are other materials that are not hydrolysed within the human digestive tract, the principal class being the resistant starches (oligosaccharides based on galactose, maltose and other sugars) and lignin. There are three forms of resistant starches:

i. Protected starch molecules
ii. Unswollen granules, e.g. potato starch
iii. Retrograded starch.

These materials are resistant to digestion in the upper reaches of the alimentary canal and arrive intact in the colon where they are digested by the microflora of the gut, a definining characteristic of dietary fibre.

The increased bulk of high-fibre foods give them greater satiety value, which is beneficial in preventing obesity. More importantly, a diet low in fibre leads toconstipation and the development of high pressures in the intestinal tract. This has been linked with the development of diverticular disease of the colon, hiatus hernia, haemorrhoids (piles), and varicose veins. All of these conditions are more common in people with a low intake of NSP, and high-fibre diets are protective.

High fibre diets lower blood cholesterol thereby reducing the risk of heart disease. Fibre will bind a proportion of the bile salts (and cholesterol itself, which is also secreted in the bile), so that they are excreted in the faeces rather than being reabsorbed, thus causing more cholesterol to be used for bile salt synthesis.

High fibre diet also reduces the risk of gallstone formation, since it results in more bile salts and less cholesterol being present in the bile – it is the insolubility of cholesterol when its concentration in bile is high that causes the formation of gallstones. Bile salts have been implicated in the development of cancer of the large intestine. However, if the salts are bound to dietary fibre rather than being free in solution, they will not be able to interact with the intestinal wall in such a way to promote the development of tumours.

Dietary fibre has two further important effects in reducing the risk of cancer. All diets contain a number of potentially carcinogenic compounds; many of these will bind to dietary fibre, and so will be unavailable for absorption into the body, and unable to interact with intestinal cells. The intestinal bacteria ferment a proportion of the dietary fibre, and some of the products of this bacterial metabolism (especially butyric acid) have anti-proliferative action (they help prevent cells from multiplying), and so will provide further protection against the development of intestinal cancer. The food sources of fibre are fruits, vegetables, cereals, whole-grain bread, wheat bran and products made from nuts and legumes.

Self- Assessment Exercises 2

1. State the three forms of resistance starches
2. Describe the effect of zinc deficiency in humans

4.6 **Summary**

Minerals are micro nutrients which can be classified into macro elements and micro in organic components which are present in foods required for good health.

Calcium and phosphorus are minerals required for bone and teeth formation. A small amount of calcium is however required in the serum which regulates nervous excitability and muscle contraction. Enzymes require magnesium for activation of the activities of muscle and nerves. Zinc is required as a cofactor in the dehydrogenases and carbonic anhydrases required in intermediary metabolism. Sodium and potassium are found in small quantities for the maintenance of acid-base and body water balance, and nerve function regulation. Blood contains haemoglobin which requires iron as a cofactor and lack of iron results in hypochromic and microcytic anaemia. Fluorine derived from water or dental sources aid in the formation of strong teeth and bones. Eating foods containing fibre have many advantages even though fibre itself is not a nutrient.

4.7 References/Further Readings

Walker, A.F (1990). Applied Human Nutrition. Aspen Publishers. 300 pages.

Belitz, H.D., Grosch, W., Schieberle, P and M.M. Burghaghen, M.M (2004). Food Chemistry. Springer, 1071 pages

Hutkins, R (2006). Microbiology and Technology of Fermented Foods – A Modern Approach. Blackwell Publishing Professional, 488 pages

International Commission for Microbiological Specifications of Foods (ICMSF) (1996). Microorganisms in Foods - Characteristics of Microbial Pathogens – Springer. 1996. 524 pages

Jay, J.M., Loessner, M.J. and Golden, D.A (2005). Modern Food Microbiology, 7th edition, Springer food science text series, 790 pages

Satin, M (1996). *Food Irradiation: A Guidebook,* 2nd edition. Lancaster, PA: Technomic Publishing.

4.8 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. Trace elements are inorganic substances that appear in the body in minute amounts but are essential for good health. E.g. zinc, iron, fluorine, etc.
2. Calcium, Phosphorus, Potassium, Magnesium, Sodium

Answers to Self-Assessment Exercises 2

1. There are three forms of resistant starches:

iii. Protected starch molecules
iv. Unswollen granules, e.g. potato starch
v. Retrograded starch.

2. Zinc deficiency in humans includes: various combinations of loss of taste, retarded growth, delayed wound healing, baldness, pustular skin lesions, growth failure, small sex glands, impotence in males, infertility in females, delayed wound healing, mental lethargy and reduced immunity to infections.

UNIT 5 THE ROLE OF VITAMINS IN NUTRITION

CONTENTS

5.1 INTRODUCTION

Vitamins are organic compounds that function mainly in enzyme systems to enhance the metabolism of proteins, carbohydrates, and fats. They are not synthesized in the body hence must be obtained from outside sources as food. Vitamin D which is synthesized in the body and vitamins B12 and K which are synthesized by bacterial flora in the intestinal tract are exceptions. Without these substances, the breakdown and assimilation of foods could not occur. Certain vitamins participate in the formation of blood cells, hormones, nervous-system chemicals, and genetic materials. Vitamins and minerals function as "cofactors" in the metabolism of products in the body. Vitamins are classified into two groups; the fat-soluble and the water- soluble vitamins. Fat-soluble vitamins include vitamins A, D, E, and K. The water-soluble vitamins include vitamin C and the B-vitamin complex.

5.2 Learning Outcomes

By the end of this unit, you will be able to:

- Discuss vitamins
- Write the fat soluble and water soluble vitamins
- Discuss dietary sources of the vitamins
- Analyse the deficiency symptoms of three named vitamins.

5.3 Fat Soluble Vitamins

5.3.1. Vitamin A

Vitamin A (Retinol) is found in animal foods, especially in liver of land animals or fish. Vitamin A exists in a variety of forms, including retinol, which is currently considered the most active form. Most of the world's population derives most or all of their vitamin A from plant foods, many of which contain the yellow-orange pigment carotene. Carotene can be converted in the human body to vitamin A. One molecule of β-carotene can be cleaved by an intestinal enzyme into two molecules of vitamin A. The pigment β- carotene occurs in fruits such as apricots, peaches, melons, mangoes and pumpkins. It is also a companion of chlorophyll, so green vegetables are good sources. Vitamin A is stored in the liver of a well-nourished adult to last about two years of deprivation.

Vitamin A functions in the body to the maintain membrane integrity, especially of epithelial cells and mucous membranes. It is essential for bone growth, reproduction and embryonic development. Vitamin A deficiency results in night blindness, in which the ability of the eye to see in dim light is impaired, permanent blindness and extremely dry skin. Excessive intake of vitamin A in children over a long period of time causes Hypervitaminosis A. Symptoms of Hypervitaminosis A consist of irritability, vomiting, loss of appetite, headache, dry and scaling of skin.

5.3.2 Vitamin D

Good sources of vitamin D are dairy products, eggs and cod liver oil. The active forms of vitamin D are ergocalciferol (vitamin D_2) and cholecalciferol (vitamin D_3), both arise in the body from ingested precursors by exposure of the skin to ultraviolet light. Vitamin D primarily regulates calcium metabolism by determining the movement of calcium from intestines to blood and from blood to bone. It interacts with parathyroid hormone and calcitonin in controlling calcium levels. Vitamin D is today more legitimately considered a hormone rather than a vitamin. In tropical countries, where exposure to sunlight is high, vitamin D deficiency is rare. Ultraviolet irradiation of food products increases their vitamin D content. Whether formed in the skin from a derivative of cholesterol or taken from the diet, vitamin D is changed in the liver to 25-hydroxyvitamin D. 25-hydroxyvitamin D is further changed in the kidney by an enzyme to 1, 25 - dihydroxyvitamin D (1, 25-$(OH)_2$ vitamin D), the active form. The best known action of activated vitamin D at the cellular level is to turn on synthesis of calcium transport protein in the cells lining of the small intestine.

Deficiency of vitamin D results in failure to absorb calcium and phosphorus, causing faulty formation of bone. In children, the syndrome is known as rickets and is manifested by deformities of the rib cage and skull and bowlegs. Adult rickets or osteomalacia, is characterised by generalised bone decalcification and, eventually, gross bone deformities. The symptoms of hypervitaminosis D consist of weakness, fatigue, lassitude, kidney stones, headache, nausea, vomiting and diarrhoea.

5.3.3 Vitamin E

Vitamin E, chemically known as alpha tocopherol, is the most active of the group of tocopherols. Vitamin E is present in seed oils, like wheat-germ oil, margarine, seeds and green leafy vegetables. Vitamin E protects fatty acids and cell membranes from oxidation. Few vitamins have been implicated for more diseases than has vitamin E, including such diverse disorders as coronary artery disease, muscular dystrophy, habitual abortion and schizophrenia. Vitamin E is relatively non-toxic and considered to have possible value in decreasing the risk of cancer.

5.3.4 Vitamin K

Vitamin K is mainly found in green leafy vegetables, egg yolk, liver, and fish oils and it is essential for synthesis by the liver of several factors necessary for the clotting of blood. The letter K came from the German Koagulationsvitamin. Vitamin K_1 occurs in some plant foods; others (the vitamin K_2 group) are formed by bacteria in the large intestine. Phylloquinone is the natural plant source of vitamin K and a synthetic derivative - menadione, is used therapeutically. Although deficiency of vitamin K rarely occurs, when it does the result is uncontrolled bleeding. It is used medically in treating specific deficiencies that occur during anticoagulant therapy, in haemorrhagic disease of the newborn, and in hepatocellular diseases.

Self- Assessment Exercises 1

1. List the fat soluble vitamins.

2. Describe the primary function of vitamin D

5.4 Water Soluble Vitamins

5.4.1 Thiamine (Vitamin B_1)

Thiamine is the first B vitamin to be identified chemically and consists of a complex organic molecule containing a pyrimidine and a thiazole nucleus. It is found in cereals, yeast, meat (pork, liver, and poultry), nuts, beans, potatoes, egg yolk, milk, peanut butter, and enriched and whole grain bread. It functions as a coenzyme in the form of thiamine pyrophosphate and is important in alcohol, some amino acids and carbohydrate intermediary metabolism. Alcoholics are at special risk of thiamine deficiency because the more alcohol a person drinks the less thiamine-containing food he consumes. Alcohol requires thiamine for its metabolism, and body’s reservoir of thiamine is smaller than for any other vitamin. It only takes about 30 days without thiamine intake prior to signs of its deficiency to appear. The symptoms of thiamine

deficiency are known as beriberi - a syndrome consisting primarily of peripheral neuritis marked by sensory and motor paralysis of the limbs and, finally, heart failure. Thiamine deficiency is prevalent during damage and most often occurs in nutritionally deficient alcoholics.
Thiamine deficiency can lead to beriberi, Wernicke’s encephalopathy in association with Korsakoff's syndrome, or a peripheral neuropathy (a disorder of the peripheral nervous system).

Beriberi is a high-output cardiac failure associated with general dilatation of small blood vessels in response to accumulation of pyruvic and lactic acids. It was formerly common in rice-eating peoples of East Asia but is now rare. In Wernicke's encephalopathy, the abnormalities are in the central part of the brain. There is progressive mental deterioration, disorientation, and a characteristic paralysis of eye movements. Like beriberi, it responds dramatically to injection of thiamine, but unlike beriberi, there may be a residual abnormality of memory. Thiamine deficiency is one of many causes of peripheral neuropathy, generally involving an impairment of the sensory, motor and reflex functions of the limbs. However, other B-vitamin deficiencies and a number of toxins can produce a similar effect. Response to nutrient therapy always takes weeks and it is advisable to treat the disease with multiple B vitamins.

5.4.2 Riboflavin (Vitamin B_2)

Riboflavin is a fluorescent yellow-green water-soluble vitamin which plays a vital role in intermediary metabolism. It has a complex organic ring structure to which the sugar ribose is joined. Riboflavin is conjugated by phosphate to yield riboflavin 5'-phosphate and by Adenine Dinucleotide to yield Flavin Adenine Dinucleotide (FAD). Both serve as coenzymes for a wide variety of respiratory proteins. Riboflavin deficiency in humans is characterised by growth failure in children, eye nerve degradation, sore throat; seborrheic dermatitis of the face and anaemia. The only established use of riboflavin is in the therapy or prevention of deficiency disease. Food sources of riboflavin include: dairy products, meat (liver, kidney, and poultry), fish, wheat, yeast, enriched and whole grain breads.

5.4.3 Niacin (Vitamin B_3)

Niacin is a water-soluble vitamin that is made in the human liver by the conversion of the amino acid tryptophan. If the protein intake is low, pre-formed niacin must be provided in the diet; if the protein intake is generous, the body makes its niacin from the tryptophan. Some animals like cats do not have this ability. Two forms of niacin exist: nicotinic acid and nicotinamide. In the body, niacin is present in Nicotinamide Adenine Dinucleotide (NAD) and Nicotinamide Adenine Dinucleotide Phosphate (NADP), which serve as coenzymes in conjunction with protein in tissue respiration and also as dehydrogenases.

Niacin deficiency causes pellagra characterised by cutaneous eruption, which at first resembles sunburn because it affects the areas of the body exposed to sunlight. The tongue becomes red and swollen, with excessive salivary secretion. Diarrhoea also occurs along with nausea and vomiting. Later, central-nervous-system symptoms appear with headache, dizziness, insomnia, depression and even overt psychosis with hallucinations and other mental disturbances.
Nicotinic acid is used in medicine as a drug that lowers the cholesterol level in the plasma. Because nicotinic acid in large doses lowers blood lipids, it has been extensively used in the therapy and prevention of arteriosclerotic vascular disease. It is also used in the treatment of pellagra. Food sources of niacin are meat, poultry, dark green vegetables, cereals, whole grain or enriched breads.

5.4.4 Pyridoxine (Vitamin B_6)

Pyridoxine is fat soluble vitamin found mostly in whole-grain cereals, vegetables and meats. It is a substituted pyridine ring structure that exists in three forms which may be converted in the body to pyridoxal-5-phosphate (PLP), the active coenzyme form. PLP functions in human metabolism in the conversion processes of amino acids, including decarboxylation, transamination and racemization.
Pyridoxine in megadoses has been taken to ameliorate the effects of premenstrual syndrome, but its efficacy has not been established. Deficiency symptoms of pyridoxine in humans consist of seborrhoea-like skin lesions of the face, increased irritability, convulsive seizures, kidney stones and neuritis resulting in degeneration of peripheral nerves. Prolonged dosage of 500 mg and above of vitamin B_6 over a period of time causes damage to peripheral nerves, with a loss of sensation in legs and hands.

5.4.5 Pantothenic Acid

Pantothenic acid is found mainly in milk products, liver, eggs, grains and legumes. Pantothenic acid is converted to coenzyme A, which plays a vital role for a variety of reactions involving transfer of 2-carbon fragments. It is also essential for the production of metabolic products crucial to all living organisms. Pantothenic acid has no specific therapeutic application but is used in the preparation of multivitamin.

5.4.6 Folic Acid

The name folic was derived from a Latin word folia meaning "leaf". Folic acid is found in animal organs, legumes, whole-grain cereals, and vegetables. Folic acid is pteroylglutamic acid. Folic acid is converted to folinic acid (5-formyl-tetrahydrofolic acid) in the body, the coenzyme form which accepts 1-carbon units important in the metabolism of many body compounds.

Folic acid plays vital role in the synthesis of DNA and its deficiency slows down or stop the replication of DNA and cell division. The requirement for folic acid is notably increased in pregnancy. Folic acid is sensitive to heat and is mostly destroyed when vegetables are over-boiled. Folic acid deficiency can occur in late pregnancy and in patients with diseases in which cell division is increased (e.g., in blood diseases or cancer). The most common cause of vitamin B_{12} deficiency is pernicious anaemia, in which absorption of the vitamin is defective because of the failure of the stomach to secrete a special protein that assists absorption of vitamin B_{12} in the lower intestine. Dietary deficiency occurs in vegetarians, who eat no animal food. It takes five or more years of such a diet before symptoms appear because the stores of vitamin B_{12} in the liver.

Folic acid deficiency in humans results in various types of anaemia and diarrhoea. Deficiency of Folic acid can also be induced by antivitamins such as methotrexate used in cancer chemotherapy.

5.4.7 Cyanocobalamin (Vitamin B_{12})

Vitamin B_{12} has the highest molecular weight compared with other vitamins and is absorbed by a complex mechanism. It has a central ringed structure called a corrin nucleus linked to an amino propanol esterified by a nucleotide, and also an atom of cobalt to which is attached a cyanide group. Almost all organisms need this vitamin but only in very small amounts. Sources of vitamin B_{12} are mainly of animal origin, namely: milk, eggs, meat, poultry, fish, liver, kidney and heart.

The ability to absorb this vitamin depends on the production of glycoprotein by the stomach. Cases of vitamin B_{12} deficiency often involve patients with defective production of this intrinsic factor - glycoprotein. Failure of absorption (pernicious anaemia) is more common than dietary deficiency. Vitamin B_{12} is found only in animal foods, thus vegans (pure vegetarians) are at risk of its deficiency. The requirement of vitamin B_{12} is only 2 mg per day. The amount of Vitamin B_{12} stored in the liver is enough to last for five years of deprivation. Vitamin B_{12} participates with folic acid in DNA synthesis so its deficiency leads to a similar anaemia.

The symptoms of Vitamin B_{12} deficiency are identical to the classical syndrome of pernicious anaemia: ineffective manufacture of red blood cells; faulty myelin synthesis, leading to paralysing neuritis (inflammation of nerves) and a failure to maintain the epithelium of the intestinal tract. Marked anaemia and generalized weakness, which eventually develop, are always fatal unless treated. Cyanocobalamin has only one established use, the treatment of this deficiency disease, but is included in many multivitamin preparations.

5.4.8 Ascorbic Acid (Vitamin C)

Ascorbic acid is a plant sugar in the acid form, hexuronic acid. It is found in almost all plant foods like citrus fruits, green leafy vegetables and tomatoes, but not in meat. It is a powerful antioxidant and is required for the formation of collagen (in wound healing). Unlike vitamins of the B complex, ascorbic acid does not act as a cofactor. Ascorbic acid is reduced to dehydroascorbic acid and is involved in oxidation-reduction reactions in the body. Vitamin C functions mainly in the formation and maintenance of intercellular ground substance and collagen in teeth, bone and connective tissue of blood vessels.

Symptoms of vitamin C deficiency are manifested mainly in bone and blood vessels: teeth loosen because dentin is absorbed and the gums become spongy and bleed easily; haemorrhages in other tissues also occur easily with the slightest trauma. Vitamin C is used to prevent and treat scurvy and many other disorders, including various dental problems. Intake of very large amounts for long periods of time can be harmful, even though vitamin C is well tolerated, as it may contribute to the formation of kidney stones in the urinary tract. A daily intake of sufficient fresh orange juice provides enough vitamin C for most purposes.

5.4.9 Biotin, Choline and Inositol

Biotin is a complex organic acid containing sulphur and is a coenzyme for several carboxylation reactions involving carbon dioxide fixation. It is synthesized by intestinal bacteria and is widespread in food products like meats, vegetables and legumes. A natural deficiency in humans is unknown, even in individuals on extremely deficient diets.

Choline, a simple amino alcohol, is a component of lecithin and of acetylcholine, the latter of which is one of the most important neurotransmitters. Unlike most vitamins, choline can be synthesised in the body, provided that methionine intake is sufficient. It is present in large amounts in egg yolk, milk and seafood. Human deficiency rarely occurs.

Inositol is an isomer of glucose, the common sugar of human diets. It is a component of certain phospholipids. No coenzyme function has been established, but inositol promotes the growth of yeast.

Self- Assessment Exercises 2

1. State the deficiency symptoms of Vitamin C.

2. List the food sources of vitamin B_{12}

5.5 SUMMARY

Vitamins are micronutrients present in the body system regulating the metabolism of proteins, fats and carbohydrates. They are mainly obtained from dietary sources although some of them can be synthesized in the body system (e.g. vitamin D) and by bacterial flora in the intestine (e.g. vitamins B_{12} and K).

Fat-soluble vitamins are usually absorbed with foods that contain fat and are broken down by bile in the liver, and the emulsified molecules pass through the lymphatic system and veins to be distributed through the arteries. Excess amounts are stored in the body's fat and in the liver and kidneys. Because fat-soluble vitamins can be stored, they do not have to be consumed every day.

With the exception of vitamin C (ascorbic acid), water-soluble vitamins belong mainly to what has been termed the B complex of vitamins. The better-known B vitamins are thiamine (B_1), riboflavin (B_2), niacin (B_3), pyridoxine (B_6), pantothenic acid, lecithin, choline, inositol, and paraaminobenzoic acid (PABA). Two other members are folic acid and cyanocobalamin (B_{12}). Yeast and liver are natural sources of most of these vitamins.

5.6 Glossary

Dissacharides: sugars that yield two Monosaccharides on hydrolysis.

Food: anything eaten by man or animal to satisfy appetite, meet physiological needs for growth, maintain all body processes and supply energy to maintain body temperature and activities.

Fungi: single-celled or multicellular organism without chlorophyll that reproduces by spores and lives by absorbing nutrients from organic matter.

Macronutrients: These are elements required in large quantity for the normal growth and development of an organism.

Micronutrients: These are nutrients that are required in minute quantity by an organism for normal growth and development e.g. a vitamin.

Monosaccharides : simple sugars and the most important of them are glucose, fructose and galactose.

Polysaccharides: polysaccharides are sugars that yield more than two monosaccharides.

Viruses: intracellular obligate parasite which can trigger dangerous infections in humans when they contaminate our food.

5.7 References/Further Readings

Walker, A.F (1990). Applied Human Nutrition. Aspen Publishers. 300 pages.

Belitz, H.D., Grosch, W., Schieberle, P and M.M. Burghaghen, M.M (2004). Food Chemistry. Springer, 1071 pages

Hutkins, R (2006). Microbiology and Technology of Fermented Foods – A Modern Approach. Blackwell Publishing Professional, 488 pages

International Commission for Microbiological Specifications of Foods (ICMSF) (1996). Microorganisms in Foods - Characteristics of Microbial Pathogens – Springer. 1996. 524 pages

Jay, J.M., Loessner, M.J. and Golden, D.A (2005). Modern Food Microbiology, 7th edition, Springer food science text series, 790 pages
Satin, M (1996). *Food Irradiation: A Guidebook*, 2nd edition. Lancaster, PA: Technomic Publishing.

5.8 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. Fat-soluble vitamins include vitamins A, D, E, and K.
2. Vitamin D primarily regulates calcium metabolism by determining the movement of calcium from intestines to blood and from blood to bone.

Answers to Self-Assessment Exercises 2

3. Symptoms of vitamin C deficiency are manifested mainly in bone and blood vessels: teeth loosen because dentin is absorbed and the gums become spongy and bleed easily; haemorrhages in other tissues also occur easily with the slightest trauma.

4. Sources of vitamin B_{12} are mainly of animal origin, namely: milk, eggs, meat, poultry, fish, liver, kidney and heart.

MODULE 2 FOOD DISTRIBUTION, MARKETINDG AND POISONING

UNIT 1 FOOD DISTRIBUTION AND MARKETING

CONTENTS

1.1 Introduction

Distribution is the hand-over of commodities to the intended beneficiaries, according to specified rations, selection criteria and priorities. Distribution is the process during which control over the commodity passes to the intended beneficiaries. The term distribution does not include the process by which commodities are procured, or the process of transportation, storage and handling, except at the final handover point.

Food enters an extensive distribution network that brings food products from the manufacturer to various retail outlets across the country and even around the world after its processing and packaging. The modern and high-speed methods of distribution like: trucks, trains, and planes combined with reliable methods of environmental enable perishable foods to be transported great distances.

1.2 Learning Outcomes

By the end of this unit, you will be able to:

- Analyse how foods are distributed
- Discuss food marketing
- Write the importance of food marketing

1.3 Food Distribution

Food distribution networks help satisfy consumer demand for variety, making available, even in remote areas, foods that are not locally grown or processed. In fact, although food distribution network is invisible to the average consumer, it plays a vital role in ensuring the availability of even the most basic foodstuffs.

Some large supermarkets have the resources to buy food products directly from processors, transport the products, and store them in warehouses until they are needed at the store. However, for independent grocery stores and other small retailers, food wholesalers fulfill these roles. One type of wholesaler is a cooperative wholesaler, which is owned by the retailers that buy from them and usually sells only to these member-owners. In contrast, voluntary wholesalers are public companies that sell to any retailers without having membership requirements. Some food is sold directly to a retail store without going through a wholesaler first. This is common for foods such as bread and dairy products that must be delivered fresh every day or every few days. Smaller manufacturers often use food brokers as agents to arrange for their products to be sent to retailers or warehouses.

Through these various distribution channels, food makes its way to food retailers, such as restaurants, fast food outlets, supermarkets, convenience stores, specialty shops, drug stores, and some department stores. Minimarkets and open market selling are the predominant means of distributing foods in Nigeria.

1.4 Market and marketing

The word market comes from the Latin word “marcatus” which means merchandise or trade or a place where business is conducted. It includes any place where persons assemble for the sale or purchase of commodities intended for satisfying human wants. Marketing encompasses a series of activities involved in moving the goods from the point of production to point of consumption. Many scholars have defined marketing and included essential elements of time, place, form and passion utility. A market is defined in terms of existence of fundamental forces of supply and demand and is not necessarily confined to a particular geographical location. Some of the definitions of market are given as follows;

1. A market is the sphere within which price determining forces operate.
2. A market is the area within which the forces of demand and supply converge to establish a single price.
3. The term market means not a particular market place in which things are bought and sold but the whole of any region in which buyers and sellers are such a free contact with one another that the prices of the same goods tend to equality, easily and quickly.

4. Market means a social institution which performs activities and provides facilities for exchanging commodities between the buyers and sellers.
5. The American Marketing Association defined a market as the aggregate demand of the potential buyers of a product/service.

A market exists when buyers wishing to exchange the money for a good or service are in contact with the sellers who are willing to exchange goods or services for money. The prices are governed both by the supply and demand forces.

Components of a market:

Components of a market are certain conditions must be satisfied for a market to exist.

1. The existence of a good or commodity for transaction.
2. The existence of buyer and sellers.
3. Business relation or intercourse between buyers and sellers.
4. Demarcation of area such as place, region, country or the whole world.

1.4.1 Classification of markets

Markets may be classified based on the different dimensions as follows;

1. On the basis of location or place of operation

(a) Village market: this is a market located in a small village, where major transaction takes place among the buyers and sellers of the village.

(b) Primary market: These markets are located in towns near the centres of production of agricultural commodities. In these markets, a major part of the produce brought for sale by the producers (farmers) themselves. Transactions in these markets usually take place between farmers and primary/village traders.

(c) Secondary or wholesale market: These are markets located at district headquarters or important trade centres or railway junctions. The major transactions in commodities in these markets take place between primary traders and wholesalers. The bulk of arrival in these markets is from other markets and produce is handled in large quantities. In secondary market, there are specialized marketing agencies performing different functions.

(d) Terminal markets: A terminal market is one where the produce is either finally disposed of to the consumers or processors or assembled for export. Merchants are well organized and use modern methods of marketing in terminal markets. Terminal markets are present in metropolitan cities or at seaports and commodity exchange exists which provides facilities of forward trading in specific commodities.

(e) Modern terminal markets: These markets are to be built, owned and operated by either a corporate, private or cooperative entity.

(f) Seaboard markets: These markets which are located near the seaboard and are mainly for the import and export of goods.

2. On the basis of area/coverage:

(**a) Local or village market:** This is a market where buying and selling activities are limited to the buyers and sellers of the same village or nearby villages. It usually exists for the perishable commodities in small quantities.

(b) Regional market: This is a market in which buyers and sellers for a commodity are drawn from a larger.

(c) National market: In this type of market, buyers and sellers are spread at the national level.

(d) World or international market: This is a market in which the buyers and sellers are drawn from more than one country or the whole world. These markets exist in the commodities which have world-wide demand and/or supply, such as coffee, machinery, gold, silver, etc. Many countries are now moving towards a regime of liberal international trade in agricultural products like raw cotton, sugar, rice and wheat.

3. On the basis of time span:

(a) Short period market: The markets which are held only for a day or few hours are called short-period markets. The products dealt with these markets are of a highly perishable nature such as fish, fresh vegetables and liquid milk. In this market, prices are governed mainly by the extent of demand rather than by the supply of the commodity.

(b) Periodic market: The periodic markets are congregation of buyers and sellers at specified places either in villages, semi-urban or urban areas on specific days and times. These markets are held weekly, bi-weekly, fortnightly or monthly according to the local traditions.

(c) Long period market: These markets are held for a longer period and the commodities traded in these markets are less perishable and can be stored for some time like food-grains and oilseeds.

(d) Secular market: The commodities traded in tsecular markets are durable in nature and can be stored for many years. Examples are markets for machinery and manufactured goods.

4. On the basis of volume of transaction:

(a) Wholesale market: In wholesale market, commodities are bought and sold in large lots or in bulk. It can be further classified as primary, secondary and terminal wholesale markets.

(b) Retail markets: In retail market, commodities are bought and sold to the consumers as per their requirement. Transaction in these markets takes place between retailers and the consumers. The retailers purchase the goods from the wholesale market and sell in small lots to the consumers. But sometimes bulk consumers also purchase from the wholesale markets. The quantity transacted in the retail markets is generally smaller than that of wholesale markets.

5. On the basis of nature of transactions:

(a) Spot or cash market: In Spot or cash market, goods are exchanged with money immediately after the sale.

(b) Forward market: In this market, the purchase and sale of a commodity takes place at time but the exchange of the commodity takes place on some specified date in future. Sometimes even on the specified date in the future, there may not be any exchange of the commodity. Instead, the difference in the purchase and sale prices are paid or taken.

6. On the basis of number of commodities in which transaction takes place:

(a) General market: In general market all types of commodities, such as food-grains, oilseeds, fibre crops, etc., are bought and sold.

(b) Specialized market: In specialized market transactions take place only in one or two commodities. Example Food grain markets, vegetables market, wool market and cotton market.

7. On the basis of degree of competition:

(a) Perfect markets: A perfect market is one with the following conditions:

(1) There are large number of buyers and sellers:

(2) All buyers and sellers have perfect knowledge of demand, supply and prices.

(3) The prices at any time are uniform over the geographical area, plus or minus the cost of transportation from surplus to deficit areas.

(4) The prices are uniform at any one place over the periods of time, plus or minus the cost of storage from one period to another.

(5) The prices of different forms of the product are uniform, plus or minus the cost of converting the product from one form to another.

(b) Imperfect markets: The conditions of perfect competition are lacking in imperfect markets. Based on the degree of imperfection, following situations may be identified;

(1) Monopoly market: In monopoly market, there is only one seller of a commodity. When there is only one buyer of a product, the market is termed as monopsony market.

(2) Duopoly market: A duopoly market is one that has only two sellers of a commodity. The market situation where there are only two buyers of a commodity is known as duopsony market.

(3) Oligopoly market: This is a market in which there are more than few but still a few sellers of a commodity. A market having a few (more than two) buyers is known as Oligopsony market.

(4) Monopolistic market competition: When a large number of sellers deal in heterogeneous and differentiated form of a commodity, the situation is called monopolistic competition. The difference is made conspicuous by different trade marks on the product. Different prices prevail for the same basic product. For example, farmers have to choose between various makes of insecticides, pump sets, fertilizers and equipment.

8. On the basis of nature of commodity:

(a) Commodity market: A market which deals with the goods and raw materials, such as wheat, barley, cotton, fertilizers, seeds, etc., are termed as commodity market.

(b) Capital market: the markets in which bonds, shares and securities are bought and sold are called capital market. Examples are Money market, share market.

9. On the basis of stage of marketing:

(a) Producing markets: These are markets located in producing areas, which mainly assemble the commodity for further distribution to other markets.

(b) Consuming markets: These are markets which collect the produce for final disposal to the consuming population. Consuming markets are generally located in areas where production in inadequate or in thickly populated urban centre. The urban areas, including cities are consuming markets for agricultural commodities.

10. On the basis of extent of public intervention:

(a) Regulated market: These are those markets in which business is done in accordance with the rules and regulations framed by the statutory market organization representing different sections involved in the marketing. The marketing costs in regulated markets are standardized and marketing practices are regulated.

(b) Unregulated markets: In unregulated markets, business is conducted without any set rules and regulations. Traders frame the rules for the conduct of the business and run the market. These markets suffer from many ills, ranging from unstandardized charges for marketing functions to imperfections in determination of prices.

11. On the basis of type of population served:

(a) Urban market: Urban market serves mainly the population residing in urban area.

(b) Rural market: The rural market to the demand originating from the rural population.

12. On the basis of market functionaries and accrual of marketing margins:

(a) Farmers market

(b) Cooperative market

(c) General market

1.4.2 Key aspects of agricultural marketing

i. Agricultural marketing comprises of all activities involved in supply of farm inputs to the farmers and movement of agricultural products from the farms to the consumers.

ii. The agricultural marketing system includes two major sub-systems namely: product marketing and input marketing. The product marketing sub-system includes farmers, primary traders, wholesalers, processors, importers, exporters, marketing cooperatives, regulated marketing committees and retailers. The input sub-system includes input manufacturers, distributors, related associations, importers, exporters and others who make available various farm production inputs to farmers.

iii. A dynamic and growing agriculture sector requires fertilizers, pesticides, farm equipments, machinery, diesel, electricity, packing material and repair services which are produced and supplied by the industry and non-farm enterprises. The expansion of farm output stimulates forward linkages by providing surpluses of food and natural fibres which require transportation, storage, milling or processing, packing and retailing. These functions are performed by the non-farm enterprises.

iv. The marketing system should be such as may bring about the overall welfare to all the segments (producers, consumers, middlemen and traders) society. Government act as a watch-dog in ensuring the interest of all the groups associated in the marketing.

v. The subject of agricultural marketing includes marketing functions, agencies, channels, efficiency and costs, price spread and market integration, producer’s surplus, government policy and research, training and statistics on agricultural marketing and imports/exports of agricultural commodities.

vi. The overall objective of agricultural marketing in a developing country like Nigeria is to help the primary producers namely: the farmers in getting the remunerative prices for their produce and to provide right type of goods at the right place, in the right quantity and quality at a right time and at right prices to the processors and/or ultimate consumers.

1.4.3 Importance of Agricultural Marketing

Agricultural marketing plays an important role in stimulating production and consumption, and
also in accelerating the pace of economic development. It is the most important multiplier of agricultural development. In the process of shifting from traditional to modern agriculture, marketing emerges as the biggest challenge because of production surpluses generated by the shift. The importance of agricultural marketing is manifested in the following;

1. **Optimization of Resource use and Output Management:** Efficient agricultural marketing system leads to the optimization of resource use and output management. It also contributes to an increase in the marketable surplus by scaling down the losses arising out of inefficient processing, storage and transportation. A well-designed system of marketing can effectively distribute the available stock of modern inputs, and thereby sustain a faster rate of growth in the agricultural sector.

2. **Increase in Farm Income:** An efficient marketing system ensures higher levels of income for the farmers reducing the number of middlemen or by restricting the cost of marketing services and the malpractices, in the marketing of farm products. An efficient system guarantees the farmers better prices for farm products and induces them to invest their surpluses in the purchase of modern inputs so that productivity and production may increase. Again, it results in an increase in the marketed surplus and income of the farmers.
3. The widening of the market helps in increasing the demand on a continuous basis and guarantees a higher income.
4. **Growth of Agro-based Industries:** Improved and efficient system of agricultural marketing helps in the growth of agro-based industries and stimulates the overall development process of the economy. Industries like cotton, sugar, edible oils, food processing and jute depend on agriculture for the supply of raw materials.
5. **Price Signals:** Efficient marketing system helps farmers in planning their production in accordance with the needs of the economy.
6. **Adoption and Spread of New Technology:** Marketing system helps farmers in the adoption of new scientific and technical knowledge. New technology requires higher investment and farmers would invest only if they are assured of market clearance at remunerative price.
7. **Employment Creation:** The marketing system provides employment to large number of persons engaged in various activities, such as packaging, transportation, storage and processing. Persons like commission agents, brokers, traders, retailers, weighmen, packagers and regulating staff are directly employed in the marketing system.
8. **Addition to National Income:** Marketing activities add value to product thereby increasing the nation's gross national product and net national product.
9. **Better Living:** The marketing system is essential for the success of the development programmes designed to uplift the population as a whole. Any plan of economic development that aims at diminishing the poverty of the agricultural population, reducing consumer food prices, earning more foreign exchange or eliminating economic waste has to pay special attention to the development of an efficient marketing for food and agricultural products.
10. **Creation of Utility:** Marketing adds cost and utilities to the product. The following four types of utilities of the product are created by marketing:

a. **Form Utility:** The processing function adds form utility to the product by changing the raw material into a finished form. With this change, the product becomes more useful than it is in the form in which it is produced by the farmer. For example, through processing, oilseeds are converted into oil, sugarcane into sugar, cotton into cloth and wheat into flour and bread.

b. **Place Utility:** The transportation function adds place utility to products by shifting them to a place of need from the place of plenty. Products command higher prices at the place of need than at the place of production.

c. **Time Utility:** The storage function adds time utility to the products by making them available at the time when they are needed.

d. **Possession Utility:** The marketing function of buying and selling helps in the transfer of ownership from one person to another. Products are transferred through marketing to persons having a higher utility from persons having a low utility.

1.4.**4 Characteristics of a Developed Market**

A developed market should possess the following characteristics:

1. A developed market should provide commodities the consumers want and are ready to pay for.
2. It should provide a wide variety of products to the consumers so that they may easily choose for themselves.
3. No harmful products should be offered for sale in the market.
4. The information on the presence of goods in the market and their relative merits should be available to all the prospective consumers.
5. There should not be any pressure on the consumers to buy products from traders.
6. The retailing services should be available in the market (together with the wholesale facilities for small consumers.
7. Prices should be fair and uniform for the products for all the category of consumers.
8. There should not be any wastage of products in the market.
9. The producer should be able to sell his surplus quickly and get a price which is consistent with the demand and supply of situation.
10. Adequate and efficient storage, transportation and processing facilities should be available. 11. Proper grading facilities should be available.
12. The methods of packaging should be as per the requirement of different farm products.

1.4.5 Problems in agricultural marketing in Nigeria

Improper Warehouses: There is absence of proper warehousing facilities in the villages and farmer is compelled to store his products in pits, mud-vessels, "Kutcha" storehouses, etc. These unscientific methods of storing lead to considerable wastage. Approximately 1.5% of the produce gets rotten and becomes unfit for human consumption. Due to this reason supply in the village market increases substantially and the farmers are not able to get a fair price for their produce. The setting up of Central Warehousing Corporation and State Warehousing Corporation has improved the situation to some extent

Lack of Grading and Standardization: Different agricultural produce are not graded properly. The practice usually prevalent is the one known as "dara" sales wherein heap of all qualities of produce are sold in one common lot. The farmer producing better qualities is not assured of a better price. Hence there is no incentive to use better seeds and produce better varieties.

Inadequate Transport Facilities: Transport facilities are highly inadequate in Nigeria and only a small number of villages are joined by railways. Bulks of the farm produce are transported by vehicles on the road.

Malpractices in Unregulated Markets: brokers, taking advantage of the ignorance, and illiteracy of the farmers, use unfair means to cheat them. Another malpractice in the market relates to the use of wrong weights and measures in the regulated markets. Wrong weights continue to be used in some unregulated markets with the object of cheating the farmers.

Inadequate Market Information: It is almost impossible for farmers to obtain information on exact market prices in different markets. So, they accept whatever price the traders offer to them. With a view to tackle this problem the government is using the radio and television media to broadcast market prices regularly. The newspapers also keep the farmers posted with the latest changes in prices. However the price quotations are sometimes not reliable and sometimes have a great time-lag. The trader generally offers less than the price quoted by the government news media.

Inadequate Credit Facilities: The safeguard of the farmer from "forced sales" is to provide him credit so that he can wait for better times and better prices. But since such credit facilities are not available, the farmers are forced to take loans from money lenders, while agreeing to pledge their produce to them at less than market prices. The co-operative marketing societies have generally catered to the needs of the large farmers and the small farmers are left at the mercy of the money lenders.

Need for Market Regulation

To improve marketing conditions and with a view to creating fair competition conditions, there is a strong need of market regulation. A regulated market is one which aims at the elimination of the unhealthy and unscrupulous practices, reducing marketing charges and providing facilities to the producer-seller in the market. Any legislative measure designed to regulate the marketing of agricultural produce in order to establish, improve and enforce standard marketing practices comes under the market regulation. The establishment of regulated market is not intended at creating an alternative marketing system. The basic objective has been to create conditions for efficient performance of private trade, through facilitating free and informal competition. In the regulated markets, the farmer is able to sell his marketed surplus in the presence of several buyers through open and competitive bidding.

Objectives of market regulation:

1. To prevent the exploitation of farmers by overcoming the handicaps in the marketing of their products.
2. To make the marketing system most effective and efficient so that farmers may get better prices for their produce and the goods are made available to the customers at reasonable prices. 3. To provide incentive prices to the farmers for inducing them to increase the production.
4. To promote and orderly market agricultural produce by improving the infrastructural facilities.

Self- Assessment Exercises 1

1. Classify market according to the number of commodities in which transaction takes place.
2. State the problems of agricultural marketing in Nigeria

1.5 Summary

Food enters an extensive distribution network that brings food products from the manufacturer to various retail outlets across the country and even around the world after its processing and packaging. The modern and high-speed methods of distribution like: trucks, trains, and planes combined with reliable methods of environmental enable perishable foods to be transported great distances.

1.6 References/Further readings

Swaroop, K.R. and Giddaiah, R (2020). Societal Changes And Its Impact On Food Habits. *International Journal Of Scientific & Technology Research,9(2):246-271.*

UNHCR (1997) Commodity Distribution; a Practical Guide for Field Staff, 77 pages

Kumar, A (2019). Food Preservation: Traditional and Modern Techniques. *Acta Scientific Nutritional Health*, 3(12): 45 – 49

Lianou, A., *et al*., (2016). "Microbiological spoilage of beverages". In The Stability and Shelf Life of Food. (Subramanian, P. ed.) Second Edition Woodhead Publishing, India, 3-42.

Jay, J.M., Loessner, M.J. and Golden, D.A (2005). Modern Food Microbiology, 7th edition, Springer food science text series, 790 pages

Sancho-Madriz, M F (2003). "Preservation of Food". In Encyclopedia of Food Sciences and Nutrition. 2nd edition, Elsevier science Ltd publisher

Banti, M (2020). Food Adulteration and Some Methods of Detection, Review. *International Journal of Research Studies in Science, Engineering and Technology*, 7(4):9-19.

Molnar, P.J. (2001). FOOD QUALITY AND STANDARDS – Vol. II - Food Quality Indices. www.eolss.net/Eolss-sampleAllChapter.aspx. 32 pages

1.7 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. On the basis of number of commodities in which transaction takes place:

(a) General market: In general market all types of commodities, such as food-grains, oilseeds, fibre crops, etc., are bought and sold.

(b) Specialized market: In specialized market transactions take place only in one or two commodities. Example Food grain markets, vegetables market, wool market, etc.

2. Problems of agricultural marketing in Nigeria

i. Improper Warehouses: There is absence of proper warehousing facilities in the villages and farmer is compelled to store his products in pits, mud-vessels, "Kutcha" storehouses, etc.

ii. Lack of Grading and Standardization: Different agricultural produce are not graded properly. The farmer producing better qualities is not assured of a better price

iii. Inadequate Transport Facilities: Transport facilities are highly inadequate in Nigeria and only a small number of villages are joined by railways. Bulks of the farm produce are transported by vehicles on the road.

iv. Malpractices in Unregulated Markets: brokers, taking advantage of the ignorance, and illiteracy of the farmers, use unfair means to cheat them. Another malpractice in the market relates to the use of wrong weights and measures in the regulated markets.

v. Inadequate Market Information: It is almost impossible for farmers to obtain information on exact market prices in different markets a great time-lag. The trader generally offers less than the price quoted by the government news media.

vi. Inadequate Credit Facilities: The safeguard of the farmer from "forced sales" is to provide him credit so that he can wait for better times and better prices.

UNIT 2 FOOD HABITS

CONTENTS

2.1 Introduction

The taste, texture and appearance of foods can also affect the people in different ways. Most foods are grown in a particular season (seasonal foods). Technology and the import of food have allowed food to be available all the year. Frozen foods such as vegetables are of a great alternative to fresh, if they are unavailable. There is a persistent level of malnutrition with over 40% of children and 36% of adults and women classified as undernourished. The reasons for such high levels of malnutrition and anemia include poverty, gender inequity, specific dietary patterns and recurrent illness, all these acting in conjunction. Patriarchy and gender discrimination contribute to malnutrition levels by early age of marriage and birth of the first child, reduced access to nutrition during critical periods like pregnancy, lactation, adolescence and the first five years of life, and less access to education and health care. Keeping girls in schools till they complete adolescence could be one of the most effective health measures. The main reasons of the malnutrition are lack of resources and Social change

2.2 Learning Outcomes

By the end of this unit, you will be able to:

- Discuss food habit
- Write the societal changes that have impact on food habit
- Analyse the implications of shift of food industry

2. 3 Societal changes that have impact on food habit

2.3.1 Age and their role in food consumption: The middle and old age groups are more calorie cautious when compared to adult and children because of the nature of urban jobs leads to obesity and diabetes and it is rapidly increasing in the developing countries when compared to the rural areas especially in old and middle age groups and there is a decrease of sugar intake, fats and animal products in them. Whenever there is an increase in disposable income people shift from plant based protein to animal based protein and processed food. The daily energy intake for the low-status strata was 1600 kcal, whereas the high-status strata consumed 3000 kcal. Even though the increase in disposable income may not lead to improvement in dietary quality, the availability of these foods is a major concern and powerful approach for selection of these dietary foods. Educated class may adopt healthy life style by choosing nutritious balanced diet, but when people have fewer choices in that area they will choose less balance diet.

2.3.2 Urban and rural area impact on food consumption: in urban areas there is more access to the processed foods rather than organic foods. So, people tend to eat ready to eat foods, which will be tasty, colorful and have more flavors even though there is no nutritional and balanced diet. People tend to attract towards these items and consume the products and it is completely laden by fats and oils and consists of animal protein this leads people to realize the adverse effects from fast foods. The processing of food has destroyed most of the advantages of the original food product with poor nutritional value. The rapid expansion of super markets, departmental stores, wholesale stores and retail stores in urban areas has given an opportunity for foreign suppliers to use this infrastructure and to provide these imported foods for more competitive price to the people. Super markets have a strong influence on food choices, weight and health of the consumers. Social facilitation effect leads to lower levels of food consumption when people eat alone and to higher levels when eating occurs in a group setting, especially when the groups are composed of familiar peop1e. Family and friends provide a source of modeling and peer pressure for consuming particular foods, including higher-fat foods, and for trying new foods.

2.3.3 Impact of Trade Policies, FDI & their role in food consumption: The changes in trade policies have resulted in the rise of meat, processed food and its consumption. It has been observed that these policies of trade liberalization have impacted health of the consumers by contributing to nutrition transition. This transition is associated with rise in the rates of people suffering from obesity and other chronic disease.Trade liberalization has led people to consume more processed and high calorie food which is poor in nutrient content and this has happened due to removal of trade barriers in foreign investment. After the incorporation of foreign direct investment (FDI) by food companies, the availability of processed food has become more evident in developing countries. FDI has brought about revolutionary change to enter in new markets. Due to this flow of FDI many global retail multinationals have come up. The increase in level of FDI has led to a nutrition transition and the processed food market takes a different turn and more unhealthy and processed food is readily available in developing countries.

2.3.4 Increase in Literacy Rate: The increase in literacy comprises the appreciation and understanding of flavour, quality, pleasure and originality of food, production and pleasant eating. Some products green wash themselves as healthier and marketing techniques also encourage purchases of food products labeled as "healthier". Health claims for one attribute of a particular product (e.g., low-fat, low cholesterol etc.) also raise issues because foods may be healthier for one reason, but rather unhealthy for other reasons.

2.3.5 Cultural and Religious Impact on Food:

Modern western culture has a major impact on the levels of consumption of foods and it should not exceed the basic need. Culture, religion and traditional knowledge affect the food, nutrition, community diet, food preferences, child feeding practices, knowledge on nutrition and other preparation and processing techniques. Some foods and drinks are taboo in certain religions and in some religions they are accepted.

2.3.6 Changes in food consumption due to working women

The managing of home and work is very tuff for working women and convenience becomes the driving factor for consumer purchases and advances in the food technology makes women to cook food in minutes and because of work and other related stress women are taking lower energy and less nutritious diet and they are mainly depending on the ready to eat foods rather than traditional organic food. The modern family seeks to improve its social position through rising in the economic ladder in which there is greater comfort and a greater promise for a better future for their children. The rural women have been working in fields and farms from time immemorial.

2.3.7 Migration:

Migration rate affects food habit globally. The rural to urban stream has the largest proportion of male migrants followed by the rural to rural stream. Amongst females, rural to rural migration is the dominant form of migration followed by rural to urban. However, the percentage of female migrants across different streams has not changed that much. In other words, it indicates that the female migration was more or less in equal intensity across all streams of migration, whereas this is not the case with male migration. Though rural to rural male migration has definitely declined, rural to urban has significantly increased in recent years with some increase in urban to urban male migration.

2.4 Implications of Shift on Food Industry

Farmers need to understand the shift in food habits and accordingly have to plan their cultivation process of crops and they need focus more on to produce the fruits, vegetables, grains which are organic because the people are becoming more health conscious and shifting their habits to eat more fruits and vegetables in urban areas. Scientists need to develop superior advanced technologies in order to improve the productivity of crops. The main shift is towards the processed food and its packaging to improve the life span of the product, and scientists need to work on storage of the food and packaging of the food to increase the life span of the product. Marketers need to use the word healthier or organic in order to make the customer to know that it is a healthier product, people are now become more health conscious so, in order to catch that market competition and to motivate the people this word should be included in packaging. Policy makers need to encourage the healthier products by banning the harmful products.

2.5 Changing Food Habits and Related Problems

Traditional food habits in themselves have rarely been the cause of malnutrition and nutritional-deficiency diseases. The usual cause of such problems has been a simple lack of food, whether because of environmental conditions or of poverty. The poor in any society may be forced to consume less food or a more limited variety of foods than they require. If the staple is protein-low (e.g. cassava or plantain based), the poor who cannot afford legumes or animal products to supplement the staple may suffer from kwashiorkor; if the staple is maize, pellagra may become prevalent if other foods are not consumed along with the maize. Advances in agricultural and food processing techniques have led to increased food supply and a nutritionally enriched diet. Nevertheless, modernization and westernization of traditional food habits have also had their deleterious effects. For example, the wide acceptance of refined rice (like Uncle Bens, Arosso, Tomato etc) at the expense of locally parboiled rice (like Ofada, Abakaliki, Ekiti etc) at the turn of the 20th century caused a scourge of beriberi (a niacin-deficiency disease) in many developing countries, resulting in thousands of deaths. The substitution of bottle-feeding for breast-feeding among poor families has also been implicated in a great deal of malnutrition and diarrheal diseases in Nigeria.

Changing food habits have had harmful effects in the affluent developed nations, as well. The proportion of energy obtained from carbohydrates has dropped significantly (often ranging from 35 to 50%), while that obtained from fats and protein – particularly animal protein is on a steady rise. The increased intake of saturated fat and cholesterol, coupled with inadequate exercises has been related to an increased prevalence of cardiovascular disease globally. In the developed countries, about 40% of the calories supplied by their diets are derived from fat and about 20% from sugar. There has also been notable increase in fat and sugar intake especially in developing countries. However, fat and sugar crowd out other foods. In a population that is largely sedentary, this tends to lead to obesity and deficiencies in iron, calcium, complex carbohydrates and fibres which can in turn, cause a host of health problems.

Self- Assessment Exercises 1

1. Describe how increase in literacy rate affect food habit
2. Write the cultural and religious impact on food habit

2.6 Summaries

The taste, texture and appearance of foods can also affect the people in different ways. Most foods are grown in a particular season (seasonal foods). Technology and the import of food have allowed food to be available all the year. Frozen foods such as vegetables are of a great alternative to fresh, if they are unavailable. Migrations, Women employment, Age, government policy, etc. have affected food habit globally and this has a negative effect on food producers. The main shift is towards the processed food and its packaging to improve the life span of the product, and scientists need to work on storage of the food and packaging of the food to increase the life span of the product.

2.7 References

Swaroop, K.R. and Giddaiah, R (2020). Societal Changes And Its Impact On Food Habits. *International Journal Of Scientific & Technology Research,9(2):246-271.*

UNHCR (1997) Commodity Distribution; a Practical Guide for Field Staff, 77 page

Kumar, A (2019). Food Preservation: Traditional and Modern Techniques. *Acta Scientific Nutritional Health*, 3(12): 45 – 49

Lianou, A., *et al*., (2016). “Microbiological spoilage of beverages”. In The Stability and Shelf Life of Food. (Subramanian, P. ed.) Second Edition Woodhead Publishing, India, 3-42.

2.8 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. The increase in literacy comprises the appreciation and understanding of flavour, quality, pleasure and originality of food, production and pleasant eating. Some products green wash themselves as healthier and marketing techniques also encourage purchases of food products labeled as "healthier". Health claims for one attribute of a particular product (e.g., low-fat, low cholesterol etc.) also raise issues because foods may be healthier for one reason, but rather unhealthy for other reasons.
2. Modern western culture has a major impact on the levels of consumption of foods and it should not exceed the basic need. Culture, religion and traditional knowledge affect the food, nutrition, community diet, food preferences, child feeding practices, knowledge on nutrition and other preparation and processing techniques. Some foods and drinks are taboo in certain religions and in some religions they are accepted.

UNIT 3 FOOD POISONINGAND IT'S CONTROL

CONTENTS

3.1 INTRODUCTION

Food poisoning refers to any condition in which a food causes a toxic reaction, whether as a result of a toxin naturally present in the food (for example, green or sprouting potatoes, partially cooked red kidney beans, many mushrooms and so on); a toxin acquired by the food as a result of natural accident (such as contamination of fish or shellfish with toxins); fungal spoilage leading to the production of mycotoxins in the food; or contamination of the food with toxins during agricultural processing (for example, pesticide residues) or food processing (such as accidental contamination with industrial chemicals). It also results from ingestion of heavy metals (intoxication) such as copper and mercury.

The term "food poisoning" is generally reserved for gastrointestinal disease resulting from bacterial or viral contamination of foods. Food poisoning or intoxication is characterized by the symptoms of nausea, vomiting, loss of appetite, fever, abdominal pain or discomfort (gastroenteritis) and diarrhea.

The most important cause of food poisoning is contamination of foods with bacteria that do not cause any obvious spoilage, so that the food is still apparently fit to eat, but may contain hazardous amounts of toxins, or sufficient numbers of bacteria to cause infection in people eating the food. In some cases the symptoms develop within a few hours of eating the contaminated food and in other cases there may be a delay of several days or even weeks before any signs of infection.

Sympyoms of food poisoning

Symptoms can vary and the length of time for the symptoms to appear depends on the source of the infection, but it can range from as little as 1 hour to as long as 28 days.
Common cases of food poisoning will typically include at least three of the following symptoms:

i. abdominal cramps
ii. loss of appetite
iii. diarrhoea
iv. vomiting
v. headaches
vi. mild fever
vii. weakness
viii. nausea

Symptoms of potentially life-threatening food poisoning include:

i. diarrhoea persisting for more than three days
ii. a fever higher than 101.5°F
iii. difficulty seeing or speaking
iv. symptoms of severe dehydration, which may include dry mouth, passing little to no urine, and difficulty keeping fluids down
v. bloody urine

3.2 Learning Outcomes

By the end of this unit, you will be able to:

- Discuss food poisoning and cross contamination
- Write the types of botulism
- Evaluate the main sources of mineral poisoning
- Write the symptoms of bacteria and mineral poisoning
- Propose measures for the control of food poisoning.

3.1 Causes and Management of Food Poisoning

3.3 Causes of Food Poisoning

Direct or indirect contamination of food can cause infections in man. The transmission of these infections by food depends on the following conditions:

i. The presence of a food that supports the growth of the microorganism.
ii. The inoculation of foods with sufficient number of microorganisms from a patient with clinical disease, or a carrier, or contaminated environment.
iii. Contamination at suitable temperatures for a period long enough to permit the growth of the organism or the elaboration of the toxin.
iv. The absence of suitable treatment or processing of the food to inactivate the organism or the toxin.
v. Ingestion of food by the host.

This series of events usually occurs in a setting where:

a. There is a reservoir of organism in man, animals, or the environment
b. Knowledge and practice of food hygiene and personal hygiene is inadequate to prevent transmission of the organism
c. Sanitation facilities are insufficient to prevent contamination of the environment with human excreta and its transfer to food.
Contamination of food leading to food poisoning can occur as a result of the way in which the food is handled and prepared. The major causes of food poisoning are:

3.3.1 Inadequate Cooking

Inadequate cooking of contaminated raw food and inadequate reheating of pre-cooked food will not produce heat sufficient enough to kill microorganisms on the food.

3.3.2 Food Storage Conditions

Cooked food should not be kept at temperatures that favour the growth of bacteria. *Bacillus cereus* forms spores that are relatively resistant to heat and these spores are commonly found on cereal grains. If cooked rice is kept warm, the spores germinate and the organisms grow and produce its toxin.

3.3.3 Cross - Contamination between Raw and Cooked Food

Cross-contamination is a problem in domestic food preparation, but may also occur, sometimes with dramatic effects, in industrial food processing.

3.3.4 Poor Personal Hygiene in Food Handlers

Personal hygiene begins at home, with the essential elements for good hygiene being a clean body, clean hair and clean clothing. Hair in food can be a source of both microbiological and physical contamination. Hairnets and beard covers should be worn to assure food product integrity. Long-sleeved smocks should be worn to cover arm hair. Clean uniforms, aprons and other outer garments that are put on after the employee gets to work can help minimize contamination. While working, clothing should be kept reasonably clean and in good repair. Removal of smocks, laboratory coats or aprons should take place when leaving the work area to go to the employee break room, restroom or exiting the building. Personal items such as meals and snacks should be stored in a locker or break room area that is located away from processing areas or areas where equipment and utensils are washed.

The only jewelry allowed in a food plant is a plain wedding band and/or one small post earring in each ear. No other jewelry is to be worn because it may fall into the product, it can present a safety hazard and it cannot be adequately sanitized against bacterial transmission. It should be removed prior to entering the processing facility. Employees must wear different colored smocks when going from a raw processing part of the establishment to the cooked processing side. They should also step into a sanitizer footbath between the two processing areas to eliminate the bacteria on their shoes.

No employee who is affected with, has been exposed to, or is a carrier of a communicable disease, the flu or a respiratory problem, or any other potential source of microbiological contamination shall work in any area where there is a reasonable possibility that food or food ingredients can be contaminated. The number one symptom of a foodborne illness is diarrhoea. Other symptoms include fever, dizziness, vomiting, and sore throat with fever or jaundice. Any employee with these symptoms should not be allowed to work around food. If an employee has been diagnosed with a foodborne illness, exclude them from the establishment, and contact the local health department. The health department must be notified if the employee has been diagnosed with one of the following foodborne illnesses: *Salmonella typhi*, *Shigella species*, *shiga* toxin producing *E. coli*, or hepatitis A virus.

3.3.5 Ingestion of Toxins

The ingestion of naturally occurring poisons present in mushrooms, toadstools, fish and shellfish and other contaminants causes food poisining. Food poisoning from mushrooms such as *Amanita phalloides* or muscaria, results in sweating, cramps, diarrhoea, confusion and sometimes convulsions. Patients usually recover within 24 hours if the infecting mushroom is *Amanita phalloides*, however, liver damage is common, leading to jaundice. Remissions may occur, but the mortality rate is about 60 percent or higher. Fish poisoning can result from Pacific types such as sea bass, Caribbean types such as Cavallas, Scrombroid types such as Mackerel, and Tetraodon types such as Puffers. Symptoms include numbness of the limbs, joint aches, chills and fever. Muscle weakness and paralysis can also occur, and death may result within 24 hours.

3.3.6 Ingestion of Heavy Metals

Ingestion of heavy metals like lead and mercury can cause acute nausea, vomiting and diarrhoea and may cause respiratory or nervous system damage over a long term. The severity of the symptoms depends on the metal and the dose, as well the patient. Treatment includes bed rest, fluids and blood or plasma expanders in severe cases where shock is anticipated.

Self- Assessment Exercises 1

1. What are the Symptoms of potentially life-threatening food poisoning?
2. Outline the major causes of food poisoning

3.4 Types of Food Poisoning Organisms

Food poisoning organisms can be classified into four groups, depending on the mechanism involved in causing disease:

a. Organisms that produce toxin in the food
b. Organisms that multiply in the intestinal tract and produce toxins that causes the symptoms
c. Organisms that invade the body but generally remain in the region of the intestinal tract or cause widespread systemic infection
d. Other microbial infection

3.4.1 Organisms that Produce Toxin in the Food

The main examples of organisms that produce toxin in the food are *Clostridium botulinum*, *Staphylococcus aureus* and some strains of *Bacillus cereus*. The problem here is more of intoxication than infection and if the food contains a significant amount of the toxin, subsequent cooking will not reduce the risk of food poisoning.

a. *Clostridium botulinum* Food Borne Poisoning

Botulism is food poisoning caused by eating food containing a poisonous bacterium called *Clostridium botulinum*. There are three main types of botulism viz: food-borne botulism caused by eating foods that contain the botulism toxin; wound botulism caused by toxin produced from a wound infected with *Clostridium botulinum* and infant botulism caused by consuming the spores of the botulinum bacteria which then grow in the intestines and release toxin. The three forms of botulism are fatal and cause medical emergencies.

Food-borne botulism is particularly dangerous because eating a batch of *Clostridium botulinum* contaminated food can poison a large number of people. The *Clostridium botulinum* is found in the soil but grows in many meats and vegetables *Clostridium botulinum* spores are killed by boiling while the toxins may be destroyed by moist heat at 80° C for 30 minutes. The spores grow best in the absence of oxygen and this makes improperly processed foods in sealed containers a perfect environment for their growth.

If food contaminated by the bacterium *Clostridium botulinum* is not properly canned or bottled, the bacteria are able to produce a toxin called 'botulin', which produces the disease botulism. Within 8 to 36 hours of ingestion of the contaminated food, the botulin toxin paralyses nerves regulating muscle function, resulting in respiratory failure, as the muscles that control breathing weaken. The toxin also affects the central nervous system and interrupts nerve impulses, but the mind continues to function normally. The symptoms of botulism usually appear 18 to 36 hours after ingestion of the contaminated food. Disability progresses from difficulty in walking and swallowing, with impaired vision and speech, to occasional convulsions, and ultimately to paralysis of the respiratory muscles, suffocation, and death, all within a few hours or days, depending on the amount of toxin ingested.

The most direct way to confirm diagnosis is to demonstrate the presence botulin in the patient's serum or stool by injecting serum or stool into mice and looking for signs of botulism. Botulism antitoxin may be effective if administered early. Surgical opening of the trachea and use of a respirator may be lifesaving. Physicians may try to remove contaminated food still in the gut by inducing vomiting or by using enemas. The respiratory failure and paralysis that occur with severe botulism may require a patient to be on a ventilator for weeks. Research into the use of botulism in biological warfare has produced a toxoid, an inactivated poison for use in a vaccine, to induce immunity.

b. Staphylococcus Food Borne Poisoning

The most common species of Staphylococcus is *Staphylococcus aureus*, which is found on the skin, mouth, external ear and in the nostrils of many healthy individuals. Another species of staphylococcus called *Staphylococcus epidermidis* is very widespread but is not normally pathogenic. These bacteria can not cause serious infections under the right conditions. They may infect wounds or give rise to endocarditis (inflammation of the heart membrane) if the host's immune system is weak. They may also cause pneumonia and internal abscesses. They do not form spores but can survive for several weeks in dry conditions. Some strains can withstand high temperatures; they do not often grow outside the body, but may do so in meat, milk or dirty water.

The various species of Staphylococcus multiply rapidly at room temperature and may directly infect the gastrointestinal tract. Due to careless food handling, workers may sneeze or cough on food or may have infected pimples or wounds on the hands or face and transmit the bacteria to the food. *Staphylococcus aureus* infections are characterised by the presence of pus and formation of abscesses.

Staphylococcus is responsible for skin pustules (pimple containing pus), boils and carbuncles (severe skin abscess), impetigo (contagious skin infection forming pimples and sores), infections of wounds and burns, breast abscesses, whitlow, osteomyelitis, bronchopneumonia, septicaemia, acute endocarditis, food poisoning and scalded skin syndrome. The Symptoms of Staphylococal infection includes nausea, vomiting and diarrhoea which develop within 1 to 8 hours after exposure to the bacteria. Treatment is usually by combination of fluid and electrolyte replacement but deaths rarely occur.

3.4.2 Organisms that Multiply in the Intestinal Tract and Produce Toxins that Causes the Symptoms

Organisms may multiply in the intestinal cavity (for example, *Bacillus Cereus* and *Clostridium perfringens*) and produce relatively rapid symptoms after eating the contaminated food and the infection lasts for only a day or so. Other organisms, including the various pathogenic strains of *Escherichia coli*, *Aeromonas species* and *Vibrio cholerae* invade and multiply inside the cells of the intestinal wall and secrete toxins. The onset of symptoms from such organisms is typically one to two days and the symptoms may last for several days.

a. *Escherichia coli* Food Borne Poisoning

E. coli infection is a potentially fatal form of food poisoning caused by certain strains of the bacterium *Escherichia coli*. About 5 million *E. coli* normally inhabit the human and animal intestinal tract, and are vital to processing vitamins in the diet. However, a number of strains are pathogenic and causes gastroenteritis. Strains known as entero-pathogenic strains are associated with undercooked meat, and are a common cause of diarrhoea in infants, but rarely produce gastroenteritis in adults. Other “entero-toxicogenic” strains are the main cause of “travellers' diarrhoea”. A relatively large number of *E. coli* (100 million or more) are normally required to cause infections, which are generally associated with food and water contaminated by faeces.

Entero-invasive strains *E. coli* invade cells of the intestines, causing dysentery, with bloody diarrhoea. These are highly virulent strains, and ingestion of just a few organisms may cause infection. Outbreaks of such infection have been associated with undercooked hamburgers and unpasteurised milk. The entero-haemorrhagic strains are also highly virulent, causing both bloody diarrhoea and possibly fatal systemic infection. In particular, the strain *E. coli* 0157:H7, which also exists in animals and humans, is thought to be a virally infected, highly toxic strain of the *E. coli*. Ingestion of as few as 10 organisms may cause intestinal haemorrhaging and possible kidney failure. The fatality rate from the infection is 50 per cent in children and the elderly. The main source of infection is undercooked contaminated beef. Once infected, people in confined areas can transmit the pathogen.

Certain rare strains of the bacteria *Escherichia coli* cause food poisoning in young children, the elderly, and people with impaired immune systems. *E. coli* 0157:H7 normally found in the intestines and faecal matter of humans and animals can survive in meat if the meat is not cooked beyond 155°F. Outbreaks are due mainly to contaminated cooked meats bought from local retail butchers. These incidences emphasize the need for improved food regulations, preparation and hygiene as bacteria from meat surfaces are incorporated during grinding and cutting, and subsequent insufficient cooking.

Symptoms of *E. coli* infection appear after four to nine days and include bloody diarrhoea, cramping, pain, and fever. Complications of *E. coli* infection include septicaemia, kidney failure and brain damage. Currently there is no cure for *E. coli* infection. Patients recover once the infection has run its course, although digestive and renal problems may persist. Prevention of *E. coli* infection is by maintaining high standards of food hygiene. The standards food hygiene includes always washing the hands before handling food, scalding the utensils used to prepare meat and keeping raw meat separate from other foods and thoroughly cooking of food to 70° C.

b. *Vibrio cholerae* Infection

Vibrio cholerae cause cholera - a severe infectious disease endemic to tropical countries and occasionally spreading to temperate climates. The major means of infection is through the use of contaminated water in the preparation of foods such as fruits and vegetables. Ready-to-eat foods may be contaminated by storage in contaminated containers or by sprinkling with contaminated water. The symptoms of cholera are diarrhoea and the loss of water and electrolytes in the stool. In severe cholera, the patient develops violent diarrhoea, vomiting, thirst, muscle cramps and sometimes, circulatory collapse. Death can occur as quickly as a few hours after the onset of symptoms. The mortality rate is greater than 50% in untreated cases, but falls to less than 1% with effective treatment. Prevention of the disease is a matter of sanitation and treatment consists mainly of intravenous or oral replacement of fluids and salts containing the correct mixture of sodium, potassium, chloride, bicarbonate and glucose. A vaccine made from dead bacteria is commercially available and offers partial protection for a period of three to six months after immunization.

3.4.3 Organisms that Invade the Body but generally remain in the Region of the Intestinal Tract and/or Cause Widespread Systemic Infection

Microorganisms like *Campylobacter, Salmonella, Shigella* and *Yersinia* remain in the intestinal tract. The onset of symptoms is relatively slow and the infection may persist for weeks. Organisms that invade and cause systemic infections in the body include *Listeria monocytogenes, Salmonella typhi* and *Salmonella paratyphi*. The onset of symptoms may occur many days after consuming the contaminated food and symptoms may persist for many weeks.

a. Salmonella Food Borne Infection

Salmonella is transmitted through contaminated poultry, eggs and other foods. Three species are recognised: *Salmonella typhi, S. cholerasius* and *S. enteritidis* which have more than 1,400 antigenically distinct serotypes. *S. typhi* cause typhoid fever. *S. typhimurium* - a serotype of *S. enteritidis* causes salmonella gastroenteritis, a type of food poisoning characterised by abdominal pain, fever, nausea and vomiting, and diarrhoea. The incubation period is 8 to 48 hours, and an attack may last from three to seven days. Mild cases usually are treated with anti-diarrhoeal remedies while more severe cases require antibiotics. *S. enteritidis* occurs in most flocks of hens, thus undercooked chicken or eggs are the usual source of infection. Careful cleaning and thorough cooking of food prevent salmonella infections.

b. Typhoid Fever

Typhoid fever is an acute infectious disease caused by the bacillus *Salmonella typhi* transmitted through milk, water, or solid food contaminated by faeces of typhoid victims or of carriers. The incubation period of *Salmonella typhi* lasts one to three weeks. The bacteria collect in the small intestine, from where they enter the bloodstream and induce the first symptoms - chills followed by high fever. Victims may also experience headache, cough, vomiting and diarrhoea. The disease spontaneously subsides after several weeks in most instances, but in about 20 percent of untreated cases the disease progresses to pneumonia, intestinal haemorrhage and even death.

Control of typhoid includes pasteurization of milk, purification of water supplies, the recognition of carriers, improvement of sewage facilities and inoculation of people exposed to the disease, such as hospital employees and travellers to areas with poor sanitary facilities.

3.4.4 Other Microbial Infection

Clostridium perfringens is found mainly in poultry products and it causes mild form of food poisoning. Symptoms last only a day and starts about 8 – 22 hours after ingestion and include abdominal pain, nausea, diarrhoea and vomiting.

Shigella is found in chicken spread, fruit and fish salad. It is characterized by sudden appearance of abdominal pains, cramps, diarrhoea, fever and vomiting with the presence of blood, pus and mucous in stools of about 35% of infected patients.

Self- Assessment Exercises 2

1. Write the four groups Food poisoning organisms can be classified into, depending on the mechanism involved in causing disease.
2. What is typhoid fever and how is it transmitted.

3.5 Control of Food Poisoning

Food hygiene is the major means of controlling food poisoning and attitude to the importance of food hygiene will depend upon their awareness, education and the standard of living they can afford. Food hygiene regulations have been brought into force in many countries of the world to protect the public and reduce the number of outbreaks of food poisoning. These regulations must be followed by anyone responsible for handling food in the food business.

3.5.1 Food Hygiene at Home and the Catering Industry

Food hygiene is divided into three main sections: personal hygiene, environmental hygiene and food hygiene practice.

a. Personal Hygiene

Prevention of food poisoning starts with personal hygiene as the food poisoning bacteria can be found on human skin, hair, and clothes, and in ears, noses, mouths and faeces. If people touch affected parts of their bodies during the preparation of food, they can transfer the bacteria to the food; hence, hands must always be washed before working with food, especially after visiting the toilet. The bacterium *Staphylococcus aureus* is found in the human nose, infected wounds and boils, so cuts and grazes must be covered to avoid food contamination. Clean and protective clothing such as aprons or overalls should also be worn during food preparation.

Food handlers should not work with food if they are suffering from or are carriers of food-poisoning infections as they can accidentally contaminate foods. Food handlers should not smoke, chew tobacco, cover their hairs and beards hats and nets or spit around food preparation areas. Always wash your hands in hot soapy water before preparing each dish at home, after changing a diaper or wiping a nose of a child, or handling any animal. Wash fruits and vegetables in lukewarm water to get rid of insects and pesticide residue. Skinning, peeling and boiling are the best ways to cleanse foodstuff.

b. Environmental Hygiene

Environments where food is stored and prepared must be kept clean and free from pests and pets. Dirt, soil and food residues can harbour bacteria and pests. Hot water with detergents solution be used to wipe down and clean surfaces, equipment, floors and walls. All utensils - cutting boards and countertops should be washed with hot soapy water after preparing each. Food waste should be regularly removed from the food preparation area. The danger zone is anywhere between 5°C and 63°C and bacteria grows very well at 37ºC. Temperature control is important; cold food must be stored correctly then cooked at a temperature high enough to kill bacteria. Although the refrigerator can inhibit the growth of dangerous bacteria, the temperature of refrigerator and freezer should not be greater than 4°C and –17°C respectively.

c. Food Hygiene Practice

The most serious cross contamination occurs between raw foods and cooked foods, so they should not be stored together or prepared using the same equipment. Keep raw meat, poultry or seafood separate from other food at all times. Never put cooked food unto a dish that formerly held raw meat, fish or poultry, unless that dish has been washed thoroughly with hot soapy water.

cook all food items thoroughly because if the internal heat of food exceeds 70°C, even briefly, almost all bacteria, viruses and parasites will be killed. Poultry should be cooked even more than that, up to 80°C. Reheated foods should be brought to a temperature of 75°C or it should be hot and steaming. Avoid eating poultry that is still pink inside, eggs with runny yolks or whites, or fish that is not yet opaque and that you cannot readily flake apart with a fork.

When dining out, make sure the restaurant you visit satisfies the health standards required by law. Take-away meals should be eaten within 2 hours from the time of purchase and If time elapses reheat the food to a temperature not less than 75°C.

3.5.2 Health Education

Health education programmes are concerned with turning knowledge into the following action:

i. Changing food habits to incorporate: boiling of drinking water, cooking all food and avoiding raw meat and fish.
ii. Taking specific precautions including: adequate cooking of food and the avoidance of foods and food preparation methods that have caused outbreaks in the past.
iii. Avoiding long delays in consuming prepared food and following approved food sanitation methods and procedures.
iv. Giving positive support to community activities such as improvement of water supply and the construction and use of latrines.
v. Accepting expert advice on food hygiene and control of enteric diseases.

Health education methods include both person-to-person contacts and the use of mass information media. The methods must be carefully chosen to match the educational level of the target group and effective use should be made of community leaders in the educational effort. The educational programme should be designed specifically for the community. The Health education programme is difficult since a number of anti-health factors exist. These anti-health factors include ignorance, superstition, lethargy, poverty and opposition from vested interests.

Self- Assessment Exercises 3

1. What are the factors that makes health education programme difficult
2. List thepossible ways of controlling food poisoning

3.6 SUMMARY

Food poisoning may occur as a result of non-control of environmental temperature requirement of foods leading to growth of microbial spores including *Clostridium* and *Staphylococcus* species. It can also occur from heavy metals contaminations and cross-contaminations.

Food poisoning can result from poor environmental and personal hygiene, storage conditions and contaminations by microorganisms and heavy metals. The most deadly and pathogenic microorganisms include 3 types of *Clostridium botulinum* and *Staphylococcus aureus.* Mineral poisoning occurs from heavy metals (lead and mercury) contaminations. Other microorganisms that cause food poisoning include:

1. *Escherichia coli* especially in children and the elderly.
2. *Vibrio cholerae* which causes cholera.
3. Salmonella transmitted through contaminated poultry, eggs and certain foods.
4. *Salmonella typhi* which causes typhoid fever is transmitted by milk, water or solid food contaminated by faeces of carriers.

The recommended control pressures against food poisoning include:

1. Good hygiene in the handling, processing and storage of foods.
2. Application of low Temperature: Refrigeration at less than $4^{o}C$ and deep-freezers at less than $17^{o}C$.
3. Application of proper Health Education by applying methods from contacts and information media.

3.7 References/Further Readings

Walker, A.F (1990). Applied Human Nutrition. Aspen Publishers. 300 pages.

Bubel, M., Bubel, N and Art, P. (1991). Root Cellaring: Natural Cold Storage of Fruits and Vegetables. 2nd ed.

Coxe, A. H and Coxe, A. H (1997). The Great Book of Sausages. Overlook, 1992, 1997. Recipes, Instructions for Making 45 Varieties, and the History and Ingredients of 600 Types of Sausages.

Belitz, H.D., Grosch, W., Schieberle, P and M.M. Burghaghen, M.M (2004). Food Chemistry. Springer, 1071 pages

Hutkins, R (2006). Microbiology and Technology of Fermented Foods – A Modern Approach. Blackwell Publishing Professional, 488 pages

International Commission for Microbiological Specifications of Foods (ICMSF) (1996). Microorganisms in Foods - Characteristics of Microbial Pathogens – Springer. 1996. 524 pages

Marriot, N.G. and Gravani, R (2006). Principles of Food Sanitation, 5th Edition. Springer, 413 pages

Swaroop, K. R. and Giddaiah, R (2020). Societal Changes and Its Impact on Food Habits. *International Journal Of Scientific & Technology Research,9(2):246-271.*

Kumar, A (2019). Food Preservation: Traditional and Modern Techniques. *Acta Scientific Nutritional Health*, 3(12): 45 – 49

Lianou, A., *et al*., (2016). “Microbiological spoilage of beverages”. In The Stability and Shelf Life of Food. (Subramanian, P. ed.) Second Edition Woodhead Publishing, India, 3-42.

Jay, J.M., Loessner, M.J. and Golden, D.A (2005). Modern Food Microbiology, 7th edition, Springer food science text series, 790 pages

Sancho-Madriz, M F (2003). “Preservation of Food”. In Encyclopedia of Food Sciences and Nutrition. 2nd edition, Elsevier science Ltd publisher

Banti, M (2020). Food Adulteration and Some Methods of Detection, Review. *International Journal of Research Studies in Science, Engineering and Technology*, 7(4):9-19.

3.8 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. Symptoms of potentially life-threatening food poisoning include:
   i. diarrhoea persisting for more than three days
   ii. a fever higher than 101.5°F
   iii. difficulty seeing or speaking
   iv. symptoms of severe dehydration, which may include dry mouth, passing little to no urine, and difficulty keeping fluids down
   v. bloody urine
2. Inadequate Cooking, Food Storage Conditions, Cross - Contamination between Raw and Cooked Food, Poor Personal Hygiene in Food Handlers, Ingestion of Toxins and Ingestion of Heavy Metals.

Answers to Self-Assessment Exercises 2

1.
   a. Organisms that produce toxin in the food
   b. Organisms that multiply in the intestinal tract and produce toxins that causes the symptoms
   c. Organisms that invade the body but generally remain in the region of the intestinal tract or cause widespread systemic infection
   d. Other microbial infection

2. Typhoid fever is an acute infectious disease caused by the bacillus *Salmonella typhi* transmitted through milk, water, or solid food contaminated by faeces of typhoid victims or of carriers.

Answers to Self-Assessment Exercises 3

1. Ignorance, superstition, lethargy, poverty and opposition from vested interests.
2. Personal hygiene, environmental hygiene and food hygiene practice.

UNIT 4 BACTERIA FOOD-BORNE INFECTIONS AND INTOXICATIONS

CONTENTS

4.1 Introduction

Foodborne illness commonly referred to as food poisoning, is the result of eating contaminated, spoiled, or toxic food. The most common symptoms of food poisoning include nausea, vomiting, and diarrhoea. Foods contaminated with pathogenic microorganisms usually do not look bad, taste bad, or smell bad. It is impossible to determine whether a food is contaminated with pathogenic microorganisms without microbiological testing. Diseases which result from pathogenic microorganisms are of two types: infection and intoxication.

i. Foodborne infection is caused by the ingestion of food containing live bacteria which grow and establish themselves in the human intestinal tract.
ii. Foodborne intoxication is caused by ingesting food containing bacteria toxins.

The following conditions must be present for a foodborne illness (poisoning) to occur:

i. The microorganism or its toxin must be present in food.
ii. The food must be suitable for microbial growth.
iii. The temperature must be suitable for microbial growth.
iv. Enough time must be given for the microorganism to grow and/or to produce a toxin.
v. The food must be eaten.

Food poisoning symptoms

Symptoms can vary and the length of time for the symptoms to appear depends on the source of the infection, but it can range from as little as 1 hour to as long as 28 days.

Common cases of food poisoning will typically include at least three of the following symptoms:

ix. abdominal cramps
x. loss of appetite
xi. diarrhoea
xii. vomiting
xiii. headaches
xiv. mild fever
xv. weakness
xvi. nausea

Symptoms of potentially life-threatening food poisoning include:

3. diarrhoea persisting for more than three days
4. a fever higher than 101.5°F
5. difficulty seeing or speaking
6. symptoms of severe dehydration, which may include dry mouth, passing little to no urine, and difficulty keeping fluids down
7. bloody urine

Causes of Food Poisoning

Bacteria and Viruses: Bacteria and viruses are the most common cause of food poisoning. The symptoms and severity of food poisoning vary, depending on the bacteria or virus that contaminated the food.

Parasites: Parasites are organisms that derive nourishment and protection from other living organisms known as hosts. Parasites in order to derive nourishment, causes harm to the host. The most common foodborne parasites are protozoa, roundworms, and tapeworms.

Moulds, Toxins and Contaminants: Most food poisoning is caused by bacteria, viruses, and parasites rather than toxic substances in the food but some cases of food poisoning can be linked to either natural toxins or added chemical toxins.

Allergens: Food allergy is an abnormal response to a food triggered by your body's immune system. Some foods, such as nuts, milk, eggs, fish, crustacean shellfish, tree nuts, peanuts, wheat or soybeans, can cause allergic reactions in people with food allergies.

4.2 Learning Outcomes

By the end of this unit, you will be able to:

- Write the symptoms of food ppoisoning
- Discuss the causes of food poisoning
- Analyse foodborne infections

4.3 Foodborne Infections

A foodborne infection is an inflammation of the stomach and bowels. The infection happens when you eat or drink foods contaminated by bacteria, virus or parasite. Often the foodborne infection leads to diarrhea, nausea, vomiting, abdominal pain, abdominal cramps and sometimes fever and can last between one and three days.

Many foodborne infections occur at people's homes, simply due to poor hygiene (preparing food without hand washing after visiting the toilet). Cross contamination is also a risk, for instance if raw meat and lettuce are both chopped on the same cutting board or even using the same knife to chop both. Eating meat or fish that is not thoroughly cooked or eating raw shellfish, increases the risk of food-borne infections.

Food borne intoxications or food poisoning is caused by ingestion of:

i. toxicants found as toxins of certain plants or animals.
ii. toxin formed by microbes while they multiply on the foods or in the intestines.
iii. poisonous substances that may be intentionally or incidentally added to foods during production, processing, transportation or storage.

Toxicants or toxic substances in food are substances that are found in foods that can produce harmful effects on ingestion by humans and animals.

4.3.1 Bacterial Intoxicants

a. Staphylococcal poisoning

i. Most common infection
ii. Caused by infection with *Staphylococcus aureus*
iii. Enterotoxins produced are heat stable.
iv. Toxin causes gastroenteritis.
v. Symptoms are dose dependent and appear within 1-6 hours after consumption of contaminated food.
vi. The symptoms can be mild or severe but include nausea, vomiting, abdominal pain, diarrhea, dehydration. It can also be fatal.
vii. Common foods implicated are custard and cream, bakery foods, poultry and ham, fermented meat and dairy products.
viii. Following proper hygiene in the preparation and storage is the best preventive measure of foodborne infection

b. Clostridium **- Botulism**

i. Infection by *Clostridium botulinum*
ii. It produces neurotoxin which is heat sensitive.
iii. Disease starts within 2 hours to 14 days after ingestion of contaminated food.
iv. Symptoms are nausea, vomiting, headache, persistent constipation followed by blurred vision.
v. Common foods implicated are fermented or smoked marine products, home cured ham and meat products.
vi. Botulism can be prevented by killing C.botulinum spores in the foods during processing, eliminating recontamination of processed food, destroying the toxin by proper heating of processed food, by proper storage, and by discarding the product that has developed signs of spoilage (off odour, bulging of cans etc.).

c. Salmonella **- Salmonellosis (Typhoid)**

i. Infection by *Salmonella* species
ii. Incubation period is 6 hours to 3 days.
iii. Major symptoms are nausea, diarrhoea and fever which may last for several days. Symptoms of Salmonella-induced gastroenteritis usually disappear without treatment after 4–7 days.
iv. Foods implicated are egg, meat, milk and their products.
v. Infection either comes from product of infected animal like meat or milk or from food handler who is a carrier of infection and has not been following strict hygiene.
vi. Infection can be prevented by strictly adhering to good cooking methods.
vii. Treatments may include: fluids to prevent dehydration, antimotility drugs to reduce cramping and stop diarrhoea, antibiotics for severe symptoms or bacteremia.

d. Rickettsia

The Rickettsiae are diverse group of bacteria some of which can be transmitted to humans through the bites of fleas, lice, ticks or mites. Several Rickettsia species are capable of causing disease in people.
These species include:

i. *Rickettsia australis* - Queensland tick typhus
ii. *Orientia tsutsugamushi* - scrub typhus
iii. *Rickettsia honei* - Flinders Island spotted fever
iv. *Rickettsia typhi* - murine typhus.

Although rickettsial infections are relatively rare, they have been reported along the eastern Australian seaboard, Flinders Island and the east coast of Tasmania, as well as the Fleurieu Peninsula in South Australia and southern coastal Western Australia.

Rickettsia prowazekii (epidemic typhus) is spread by human body lice and can result in outbreaks of disease but is only seen in conflict settings and refugee camps and is not naturally occurring.
Rickettsiae are usually injected directly from the saliva of ticks and mites as they feed on humans and, in the case of fleas, by contamination of bite sites by faeces.

There is great variation in the range and severity of symptoms experienced. Commonly a small, hard, black sore (called an eschar) first appears at the bite site where the infection was introduced. Other typical symptoms may include: fever, headache, muscle aches, swollen lymph glands, cough, Rash and Less common severe infections can be associated with confusion and breathing difficulties. Treatment is usually with the tetracycline antibiotic doxycycline which reduces the duration and severity of infection.

4.3.2 Fungal Intoxicants:

a. Mycotoxins: Mycotoxins are toxic compounds naturally produced by certain types of fungi (moulds). Moulds that can produce mycotoxins grow on numerous foodstuffs such as cereals, dried fruits, nuts and spices. Mould growth can occur either before harvest or after harvest, during storage, on/in the food itself often under warm, damp and humid conditions. Most mycotoxins are chemically stable and survive food processing.
Several hundred different mycotoxins have been identified, but the most commonly observed mycotoxins that present a concern to human health and livestock include aflatoxins, ochratoxin A, patulin, fumonisins, zearalenone and nivalenol/deoxynivalenol. Mycotoxins appear in the food chain as a result of mould infection of crops both before and after harvest. Exposure to mycotoxins can happen either directly by eating infected food or indirectly from animals that are fed with contaminated dairy products.
The effects of some food-borne mycotoxins are acute with symptoms of severe illness appearing quickly after consumption of food products contaminated with mycotoxins. Other mycotoxins occurring in food have been linked to long-term effects on health, including the induction of cancers and immune deficiency.
b. Aflatoxin: Aflatoxin is one of the most poisonous mycotoxins produced by moulds (*Aspergillus flavus* and *Aspergillus parasiticus*) which grow in soil, decaying vegetation, hay, and grains. Crops that are frequently affected by *Aspergillus* spp. include cereals (corn, sorghum, wheat and rice), oilseeds (soybean, peanut, sunflower and cotton seeds),

spices (peppers, coriander, turmeric and ginger) and nuts (pistachio, almond, walnut, coconut and Brazil nut).

The toxins can also be found in the milk of animals that are fed contaminated feed and can be life threatening by causing damage to the liver. Aflatoxins have also been shown to be genotoxic (they can damage DNA) and cause cancer in animal species.

There are four types of aflatoxins named B_1, B_2, G_1, and G_2 and can be categorized based on two characteristics: Their fluorescence color under UV light (blue or green), and their mobility during Thin Layer Chromatography (TLC)

c. Patulin: Patulin is a mycotoxin produced by a variety of moulds, particularly *Aspergillus*, *Penicillium* and *Byssochlamys*. It is found in decaying apples and apple products, mouldy fruits, grains and other foods.

Major human dietary sources of patulin are apples and apple juice made from affected fruit. The acute symptoms in animals include liver, spleen and kidney damage and toxicity to the immune system. Nausea, gastrointestinal disturbances and vomiting have been reported in humans. Patulin is considered to be genotoxic but a carcinogenic potential has not been demonstrated yet.

d. **Ochratoxin** A

Ochratoxin A is a common food-contaminating mycotoxin produced by several species of *Aspergillus* and *Penicillium*.

Contamination of food commodities like cereals and cereal products, coffee beans, dry vine fruits, wine and grape juice, spices and liquorice, occurs worldwide. Ochratoxin A is formed during the storage of crops and is known to cause a number of toxic effects in animal species. The most sensitive and notable effect is kidney damage, but the toxin may also have effects on fetal development and on the immune system. The most important ochratoxin is the Ochratoxin A, which is produced mainly by *Aspergillus ochraceus* and its chemical formula is $C_{20}H_{18}ClNO_6$

4.3.3 Viruses

Viral - hepatitis

Hepatitis is an inflammation of the liver that results in diffuse hepatic cell death and may lead to areas of liver necrosis. It can be classified as acute or chronic (lasting > 6 months) and may progress to fulminant liver failure, cirrhosis, and, in some cases, hepatocellular carcinoma. Hepatitis may result from infectious (e.g., bacterial, viral, parasitic or fungal) and noninfectious causes (e.g., drugs, metabolic diseases, alcohol, autoimmune diseases).

Viral hepatitis is most commonly caused by hepatitis viruses (hepatitis A, hepatitis B, and hepatitis C) and herpes viruses (cytomegalovirus, Epstein-Barr virus, varicellazoster virus, herpes simplex virus).

Common symptoms of hepatitis include fever, nausea, vomiting, fatigue, jaundice, right-upperquadrant abdominal tenderness, and dark urine and

pale stools. Extra-hepatic manifestations such as amenorrhea, arthritis, skin rash, vasculitis, thyroiditis, gynecomastia, glomerulonephritis, polyarteritis nodosa, and Sjögren's syndrome may occur in chronic hepatitis. Complications of chronic hepatitis include cirrhosis, progressive liver failure, and development of hepatocellular carcinoma.
Hepatitis A Virus Infection (HAV) is a self-limiting acute hepatitis that does not result in a carrier state or chronic disease. Transmission occurs via the fecal-oral route and most commonly results from poor hygienic practices and inadequate sanitation.
Hepatitis B Virus Infection (HBV) causes a mild or subclinical acute hepatitis but may result in chronic hepatitis or an asymptomatic carrier state. Most symptoms last 1-3 months, although fatigue can last longer. Progression to chronic hepatitis is most common in perinatal infections and young children. Transmission occurs via blood and body fluids (e.g., unprotected sex, intravenous drug use, blood transfusions, tattoos, and body piercing).

Hepatitis C Virus Infection (HCV) is the most common cause of chronic hepatitis and most common indication for liver transplantation. Acute hepatitis C is usually asymptomatic, but many cases do progress to chronic hepatitis.
Hepatitis D Virus Infection (HDV) is dependent on co-infection with the hepatitis B virus. If hepatitis D is acquired at the same time as hepatitis B, complete recovery can be expected. However, hepatitis D occurring as a super infection in a hepatitis B patient can cause a syndrome of accelerated hepatitis, with progression to chronic hepatitis within weeks. Transmission occurs via blood and body fluids (e.g., unprotected sex, intravenous drug use, blood transfusions, tattoos, and body piercing).
Hepatitis E Virus Infection (HEV) causes a self-limiting and mild acute hepatitis. However, the disease may be severe in pregnant women where it may progress to acute onset of liver failure, with 25% mortality rate. The virus is most commonly spread by fecal-oral route, blood and blood products in endemic areas.

4.3.4 Worm - Trichinosis

Trichinosis also known as trichinellosis is a type of roundworm infection. Infection occurs primarily among meat-eating animals such as bears and foxes, or meat- and plant-eating animals such as domestic pigs and wild boar. The infection is acquired by eating roundworm larvae in raw or inadequately cooked meat.
When humans eat undercooked meat containing *Trichinella* larvae, the larvae mature into adult worms in the intestine over several weeks. The adult worms then produce larvae that travel through various tissues, including muscle. Trichinosis is most widespread in rural areas throughout the world. Trichinosis is easy to treat and prevent.

Abdominal symptoms can occur one to two days after infection and other symptoms usually start two to eight weeks after infection. Mild cases of trichinosis - those with only a small number of parasites in their body may not cause recognizable signs or symptoms. Symptoms can develop with moderate or heavy infestation, sometimes progressing as the parasite travels through the body.
People get trichinosis when they eat undercooked meat such as pork, bear, walrus or horse that is infected with the immature form (larvae) of the *Trichinella* roundworm. Naturally, animals are infected when they feed on other infected animals. Pigs and horses can become infected with trichinosis when they feed on garbage containing infected meat scraps. Cattle don't eat meat, but some cases have been linked to eating beef that was mixed with infected pork or ground in a grinder previously used for contaminated pork. Wild animals, including bear, continue to be sources of infection. The best defense against trichinosis is proper food preparation.

Self- Assessment Exercises 1

1. State the conditions must be present for a foodborne illness (poisoning) to occur.
2. Discribe the causative agents of food poisoning.

4.4 Summary

The foodborne infection happens when you eat or drink foods contaminated by bacteria, virus or parasite. The most common symptoms of food poisoning include nausea, vomiting, and diarrhoea. Foods contaminated with pathogenic microorganisms usually do not look bad, taste bad, or smell bad. It is impossible to determine whether a food is contaminated with pathogenic microorganisms without microbiological testing. Food spoilage organisms include the Bacteria, Fungi, Parasites, Viruses, Worms, etc. or toxins produced by microorganisms.

4.5 Glossary

Distribution: the hand-over of commodities to the intended beneficiaries, according to specified rations, selection criteria and priorities.
Market: any place where persons assemble for the sale or purchase of commodities intended for satisfying human wants.
Mycotoxins: toxic compounds naturally produced by certain types of moulds.
Parasites: organisms that derive nourishment and protection from other living organisms known as hosts.

Toxicants : substances that are found in foods that can produce harmful effects on ingestion by humans and animals.

4.6 References/Furter Readings

Swaroop, K.R. and Giddaiah, R (2020). Societal Changes And Its Impact On Food Habits. *International Journal Of Scientific & Technology Research,9(2):246-271.*

UNHCR (1997) Commodity Distribution; a Practical Guide for Field Staff, 77 pages

Kumar, A (2019). Food Preservation: Traditional and Modern Techniques. *Acta Scientific Nutritional Health*, 3(12): 45 – 49

Lianou, A., *et al*., (2016). "Microbiological spoilage of beverages". In The Stability and Shelf Life of Food. (Subramanian, P. ed.) Second Edition Woodhead Publishing, India, 3-42.

4.7 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. The following conditions must be present for a foodborne illness (poisoning) to occur:
   - i. The microorganism or its toxin must be present in food.
   - ii. The food must be suitable for microbial growth.
   - iii. The temperature must be suitable for microbial growth.
   - iv. Enough time must be given for the microorganism to grow and/or to produce a toxin.
   - v. The food must be eaten.
2.

- **Bacteria and Viruses:** Bacteria and viruses are the most common cause of food poisoning. The symptoms and severity of food poisoning vary, depending on the bacteria or virus that contaminated the food.
- **Parasites**: Parasites are organisms that derive nourishment and protection from other living organisms known as hosts. Parasites in a order to derive nourishment, causes harm to the host. The most common foodborne parasites are protozoa, roundworms, and tapeworms.
- **Molds, Toxins and Contaminants:** Most food poisoning is caused by bacteria, viruses, and parasites rather than toxic substances in the food but some cases of food poisoning can be linked to either natural toxins or added chemical toxins.
- **Allergens**: Food allergy is an abnormal response to a food triggered by the body's immune system. Some foods, such as nuts, milk, eggs, fish, crustacean shellfish, tree nuts, peanuts, wheat or soybeans, can cause allergic reactions in people with food allergies.

MAIN CONTENT

MODULE 3

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Unit 2 Food Processing Operations II: Use of Irradiation and Moisture Reduction
Unit 3 Food processing operations III: Use of Additives, Modified Atmosphere and Fermentation
Unit 4 Processing of Roots, Tubers, Cereals and Legumes
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UNIT 1 FOOD PROCESSING OPERATIONS I: TEMPERATURE BASED PROCESSES

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1.1 INTRODUCTION

Heat is used to inactivate organisms or enzymes of spoilage significance in the foods. Microorganisms are killed by heat because heat coagulates the food proteins and inactivates the microbial enzymes and thus results in death of microorganisms. The examples include all forms of cooked food, pasteurization, milk sterilized by UHT (ultra-high temperature), canning etc.

1.2 Learning Outcomes

By the end of this unit, you will be able to:

- Discuss food processing
- Analyse the different food processing methods.
- Discuss food processing by canning, blanching, packaging and cooking.

1.3 Food Processing Operations

Effective methods of food processing have been the subject of research by man since civilization. Despite the endeavours, millions of people regularly lack sufficient food for good health while others suffer the consequences of food contamination by microorganisms. The areas of the world with the greatest nutritional deficit are those with problems of inadequate food production, distribution and preservation.

The shelf life of many perishable foods such as meat, eggs, fish, poultry, fruits, vegetable and baked products is limited in the presence of atmospheric oxygen, growth of aerobic spoilage microorganisms and attack by insect pests. Each of these factors, alone or in conjunction with one another, result in changes in colour, flavour, odour and overall deterioration in food quality.

Many kinds of agents are potentially destructive to the agreeable and healthy characteristics of fresh foods. Microorganisms, such as bacteria and fungi, rapidly spoil food. Enzymes, which are present in all raw foods, are catalytic substances that promote degradation and chemical changes affecting especially texture and flavour. Atmospheric oxygen may react with food constituents, causing rancidity or colour changes. Equally as harmful are infestations by insects and rodents, which account for tremendous losses in food stocks and a wide variety of other chemical, biochemical, or physical factors. Most processing processes are therefore aimed at destroying or inhibiting bacteria, moulds, and yeasts.

1.3.1 Thermal Processing

Thermal processing is defined as the combination of temperature and time to eliminate a desired number of microorganisms from a food product. High temperature processing is based on the principle that microorganisms and enzymes have optimum conditions, which if altered, inhibits their activities. It is also aimed at breaking the bonds in different food substances (glycosidic bonds in carbohydrates, peptide bonds in proteins, pi and sigma bonds in lipids) and making the nutrients available to the body.

The objective and intensity of a heat treatment is determined, to a large extent, by the nature of the food, the microorganisms that proliferate on it, the degree of contamination, the heat resistance of the microorganisms and their spores, heat transfer characteristics of the food, the condition of storage of the food as well as the pH of the food. Heat treatment to foods can be achieved by the following methods:

1.3.1.1 Pasteurization (temperature below 100°C)

Pasteurization is the application of heat to a food product to destroy pathogenic microorganisms, inactivate spoilage-causing enzymes and reduce/destroy spoilage microorganisms. The relatively mild heat treatment used in the pasteurization process causes minimal changes in the sensory and nutritional characteristics of foods compared to the severe heat treatments used in the sterilization process.

Pasteurization is a heat treatment involving temperatures below 100°C that kills a part but not all the microorganisms present in food. Milk, for example, is usually heated to 63°C for 30 min or 71°C for 15 seconds or in UHT 138°C for 2-4 seconds. Milk, wine, beer, fruit juices and aerated waters are routinely pasteurized products. The mode of heating can be steam, hot water, dry heat or electric currents. The products are cooled promptly after the heating and are usually supplemented by other methods to prolong shelf-life.

Pasteurization is a mild heat treatment for relatively brief duration to kill part of the microorganisms and to eliminate human pathogens present in food. It is used specially when the aim is to kill pathogenic microorganisms and where the spoilage organisms are not very heat-resistant, and the product cannot stand high-temperatures or frozen.

The main purpose of pasteurization in low acid foods is destruction of pathogenic microorganisms whereas in acid foods it aims at killing spoilage microorganisms along with enzyme inactivation. For example pasteurization is used to kill pathogenic microorganisms such as *Brucella abortis*, *Mycobacterium tuberculosis* and *Coxiella burnetti* in case of milk (63°C for 30 minutes; 71.5°C for 15 seconds) and spoilage microorganisms in beers (lactic acid bacteria and yeasts at 65°C–68°C for 20 minutes in bottle), fruit juices (yeast and fungi along with pectinesterase and polygalacturonase inactivation at 65°C for 30 minutes; 77°C for 1 minute; 88°C for 15 seconds) etc. In addition to destroying some microorganisms, pasteurization also inactivates some enzymes but does not change the colour and flavour to any significant level.

Since pasteurization does not kill all the microorganisms, this process is usually combined with another preservation method like refrigeration, freezing, etc. The index microorganism for pasteurization is *Mycobacterium tuberculosis*. If this microorganism is killed by pasteurization it is assumed that all other pathogens are also destroyed.

Pasteurisation is dependent on temperature and time. It can be High Temperature Short Time (HTST) or Low Temperature Long Time (LTLT). This involves either heating the food at a high temperature for a very short period or heating it at a low temperature for a long period. For sensitive foods (e.g. milk), flash pasteurization (HTST) is used. The temperature and time requirements of the pasteurization process are influenced by the pH of the food. When the pH is below 4.5, spoilage microorganisms and enzymes are the main targets of pasteurization.

Since the heat treatment of pasteurization is not severe enough to render product sterile, additional methods such as refrigeration, fermentation, or the addition of chemicals are often used to control microbial growth and to extend the shelf life of a product. For example, the pasteurization of milk does not kill thermoduric bacteria, such as *Lactobacillus* and *Streptococcus*, or thermophilic bacteria, such as *Bacillus* and *Clostridium*. Therefore, pasteurized milk must be kept under refrigerated conditions.

Liquid foods such as milk, fruit juices, beers, wines and liquid eggs are pasteurized using plate-type heat exchangers. Wine and fruit juices are normally de-aerated prior to pasteurization in order to remove oxygen and minimize oxidative deterioration of the products. Plate-type heat exchangers consist of a large number of thin, vertical steel plates that are clamped together in a frame. After the pasteurization process is completed, the product is packaged under aseptic conditions to prevent recontamination of the product.

Methods of pasteurization

Three methods of pasteurization are used namely: low temperature long time (LTLT), high temperature short time (HTST) and ultra-high temperature (UHT) method.

Low temperature long time (LTLT) method: In LTLT pasteurization, the time is in the order of minutes and related to the temperature used; two typical temperature/time combinations are used: 63 to 65°C for over 30 minutes or 75°C for over 8 to 10 minutes. The minimal heat treatment for market milk is 62.8°C for 30 minutes in (LTLT) holding method and for grape juice is 76.7°C for 30 minutes.

High temperature short time (HTST) method:

High pasteurization involves temperatures of about 85° to 90°C or more and time in the order of seconds. HTST method involves temperature of 71.7°C for about 15 seconds for milk and 81 to 85°C for one minute for grape wines pasteurization.

Ultra high temperature (UHT) method: Rapid, high or flash pasteurization involves temperatures of 85-90°C or more and time in order of seconds. These are also known as ultra-high temperature (UHT) treatments. Typical temperature/time combinations may be 88°C for 1 minute; 100°C for 12 seconds; 121°C for 2 seconds. This treatment will destroy all but the most heat resistant spores resulting in commercially sterile product. The 121°C for 2 seconds treatment gives the best quality products in respect of flavour and vitamin retention. Very short holding times to the tune of seconds, however, require special equipment which is more difficult to design and generally is more expensive than the LTLT/ HTST type of processing equipment.

1.3.1.2 Sterilization

Sterilization is the complete destruction of microorganisms including spores and requires heat treatment of 121°C for 15 minutes. But it has severe effect on heat sensitive nutrients and proteins through maillard reaction. The temperature and time required to sterilize the food varies with the type of food. Such high temperatures can be created by steam under pressure in steam pressure boilers/ sterilizers.

Sterilization cannot be achieved without destruction of the nutrients in the food which makes the food of no value. As such, sterilization cannot be used for food items but can only be applied as commercial sterilization, which means the same as pasteurization. Heat and chemicals can be used to achieve sterilization.

Sterilization is designed to destroy all viable microorganisms in foods. When foods are thermally processed, they are referred to as being commercially sterile (the food material is free of microorganism and their spores under normal storage conditions). The most heat resistant microorganism, *Bacillus stearothermophillus* is used as the indicator organism in sterilization operations. The presence or absence of this organism is a measure of the efficiency of the heat treatment given to a food item.

Commercial sterilization: Commercial sterility is achieved when all pathogenic and toxin forming microorganisms have been destroyed along with the spoilage microorganisms. Usually, the target organism is a heat resistant microorganism, most often a spore or schlerotia forming organism rather than a vegetative one (spore forming anaerobic bacteria – *Clostridium botulinum*). Such foods may contain viable spores, but these are not able to grow under normal conditions. These products generally have a shelf life of 2 years or more and if packaged aseptically, these products can be marketed without refrigeration.

1.**3.1.3 Tyndallisation**

This is also pasteurization with special attention on the spores. It involves heating the food item to about 80 – 100^{o}C to destroy the vegetative pathogens, then allowing it to cool to about 37^{o}C so that the spores can gamete. This cycle (heating and cooling) is repeated until satisfactory level of microbial destruction has been achieved. This method is more reliable than pasteurization since spores are taken into consideration. However, this process is accompanied by severe nutrient losses in the food item so processed.

1.3.1.4 Aseptic Processing

The aseptic process involves placing a sterilized product into a sterilized package that is then sealed under sterile conditions. However, because of unreliable machinery, it remained commercially unsuccessful until 1948 when William McKinley Martin helped develop the Martin system, which later became known as the Dole Aseptic Canning System. This system involves the sterilization of liquid foods by rapidly heating them in tubular heat exchangers, followed by holding and cooling steps.

Cold sterile products are then filled into sterilized cans and sealed in an atmosphere of superheated steam. By the 1980's, the use of hydrogen peroxide became popular for the sterilization of polyethylene surfaces.

1.3.1.5 Commercial Sterility

In aseptic processing the thermal process is based on achieving commercial sterility - no more than 1 non-sterile package for every 10,000 processed packages. The aseptic process uses the HTST method in which foods are heated at a high temperature for a short period of time. The time and temperature conditions depend on several factors, such as size, shape and type of food. The HTST method results in a higher retention of quality characteristics, such as vitamins, odour, flavour and texture, while achieving the same level of sterility as the traditional canning process in which food is heated at a lower temperature for a longer period of time.

The heating and cooling of liquid foods are carried out using metal plate heat exchangers. These heat exchangers have large surface areas that result in improved heating and cooling rates.

Liquid foods that contain large solid particles are heated in scraped-surface heat exchangers which use blades to continuously scrape the inside surface of the heating chamber. The scraping action protects highly viscous foods from being burned on the heating surface.

Another method often used for heating foods is called ohmic heating which involves passing a low-frequency electric current of 50 to 60 Hertz directly through the food. Liquid foods containing solids (e.g. diced fruit) is pumped through a pipe surrounded by electrodes. The product is heated as long as the electrical conductivity of the food is uniform throughout the entire volume. This uniform rate of heating prevents the over-processing of any individual region of the food. Ohmic heating yields a food product of higher quality than those processed using conventional systems.

Packaging Aseptically Processed Products

The packaging containers used in aseptic processing are sterilized separately before usage. The packaging machine is sterilized using steam, sterile gases or hydrogen peroxide. The sterilization process is generally monitored by culturing a test organism. For example, the presence of the highly heat-resistant bacterium, *Bacillus subtilis*, can be used as a marker to measure the completeness of sterilization. Packages must be sealed under sterile conditions, usually using high-temperature sealing plates. Foods that are aseptically processed do not require refrigeration for storage.

1.3.1.6 Canning (temperature above 100°C)

Canning is the process in which the foods are heated in hermetically sealed (airtight) jars or cans to a temperature that destroys microorganisms and inactivates enzymes that could be a health hazard or cause spoilage of food. The vacuum seal formed after heating and cooling in the process ensures that no microorganism can get into the product. The degree of heat and the length of time of heating vary with the type of food and nature of microorganisms in it. High-acid foods such as fruits and tomatoes can be processed or "canned" in boiling water, while low-acid vegetables and meats must be processed in a pressure canner at 121°C (15 psi). Examples of food preserved by canning are- all kinds of tinned foods, such as soup, meat, beans, cereal grains, legumes, nuts, and other various dried food products such as fruit, coffee, milk, soups, fish, meat and vegetables. It is also used for products such as fruit juices, syrups, and sauces. Canning is the process of applying heat to food that’s sealed hermetically in a jar to destroy any microorganism that can cause food spoilage. Canning process is advantageous in retaining the stable vitamins and colour and flavour of food items.

Canning of foods normally involves exposure for longer periods of time to higher temperatures created by steam under pressure in order to kill endospore forming microorganisms. Steam under pressure is the most effective method since it kills all vegetative cells and spores. The heat treatment generally exceeds 100°C temperature and the foods are heated long enough to inactivate the most heat-resistant pathogens and spoilage organisms. Heating to such high temperatures is achieved by steam injection, which is followed by rapid cooling. Factors that affect the length of time the food must be heated include the kind and number of microorganisms present, acidity of foods and presence of preservatives. The only dangerous spore forming bacterium which survives the treatment is *Clostridium botulinum*. The whole process of canning includes preparation of food, filling, exhausting, sealing, and thermal processing (autoclaving and cooling).

These cans had a double sealed top and bottom to provide an airtight seal and could be manufactured at high speeds. The establishment of the canning process on a more scientific basis did not occur until 1896, when Émile van Ermengem discovered the microorganism *Clostridium botulinum*, with its lethal toxin causing botulism. Canned food stored in Antarctica near the South Pole remained edible after 50 years. Such long-term preservation cannot however be duplicated in the hot climate of the Tropics.

Pre-Canning Procedures

Some crop varieties are grown specifically for canning purposes and their harvesting schedules are carefully selected to conform to the canning operations. A typical canning operation involves cleaning, filling, exhausting, can sealing, heat processing, cooking, labeling, casing, and storage. Most of these operations are performed using high-speed, automatic machines. Cleaning involves the use of shakers, rotary reel cleaners, air blasters, water sprayers or immersion washers. Any inedible or extraneous material is removed before washing, and only potable water is used in the cleaning systems.

Automatic filling machines are used to place the cleaned food into cans or other containers, such as glass jars or plastic pouches. When foods containing trapped air, such as leafy vegetables, are canned, the air must be removed from the cans prior to closing and sealing of the lids by a process called exhausting. Exhausting is accomplished using steam exhaust hoods or by creation of a vacuum. Immediately after exhausting, the lids are placed on the cans and the cans are sealed. An airtight seal is achieved between the lid and the rim of the can using a thin layer of gasket. The anaerobic conditions prevent the growth of aerobic microorganisms. **Sterilization**

A lot of factors influence the time and temperature required for the sterilization of foods. These factors includes: type of microorganisms found on the food, size of the container, acidity (pH) of the food and the method of heating. The thermal processes of canning are generally designed to destroy the spores of the bacterium - *C. botulinum*. This microorganism can easily grow under anaerobic conditions, producing the deadly toxin that causes botulism. Sterilization requires heating to temperatures greater than 100° C (212°F). However, *C. botulinum* is not viable in acidic foods that have a pH less than 4.6. The sterilization of low-acid foods (pH greater than 4.6) is generally carried out in steam vessels called retorts at temperatures ranging from 116 – 129°C (240 - 265°F). At the end of the heating cycle, the cans are cooled under water sprays or in water baths to approximately 38°C (100°F) and dried to prevent any surface rusting. The cans are then labeled, placed in fibre board cases either by hand or machine and stored in cool, dry warehouses.

Quality of Canned Foods

The sterilization process is designed to provide the required heat treatment to the slowest heating location inside the can, called the cold spot. The areas of food farthest from the cold spot get a more severe heat treatment that may result in over-processing and impairment of the overall quality of the product. The use of flat, laminated pouches reduce heat damage caused by over-processing. Canning has no major effect on the carbohydrate, protein, or fat content of foods but causes a significant loss of nutrients, especially heat-labile vitamins. Vitamins A, D and beta-carotene are resistant to the effects of heat. However, vitamin B_1 is sensitive to thermal treatment and the pH of the food. Although the anaerobic conditions of canned foods have a protective effect on the stability of vitamin C, it is destroyed during long heat treatments. The ends of processed cans are slightly concave because of the internal vacuum created during sealing. Any bulging of the ends of a can may indicate deterioration in quality due to mechanical, chemical or physical factors and may lead to swelling and possible explosion of the can.

Blanching

Blanching refers to brief immersion of fruits, vegetables, and so on in boiling water or steam. It is a thermal process used mostly for vegetable tissues prior to freezing, drying, or canning. Blanching serve several purposes, namely: cleaning of the product, reducing the microbial load, removing any entrapped gases, wilting the tissues of leafy vegetables so that they can be easily put into the containers and also inactivates enzymes that cause deterioration of foods during frozen storage.

Blanching is carried out at temperatures close to 100°C (212°F) for 2 - 5 minutes in either a water bath or a steam chamber. Because steam blanchers use a minimal amount of water, extra care must be taken to ensure that the product is uniformly exposed to the steam. Steam blanching of leafy vegetables is difficult because they tend to clump together. The effectiveness of the blanching treatment is determined by measuring the residual activity of an enzyme called peroxidase and catalase responsible for many browning reactions in many fruits and vegetables.

Blanching is commonly used for plant materials, it has been proposed for fish in order to kill cold-adapted bacteria on their outer surface. This brief heat treatment is designed to accomplish the following:

i. Inactivation of most of the plant enzymes which might cause toughness, change in colour, mustiness, loss in flavour, softening and loss in nutritive value.
ii. Reduction (up to 99 percent) in the microbial load of the food.
iii. Enhancement of the green colour of vegetables such as peas, broccoli, and spinach.
iv. Wilting of leafy vegetables such as spinach, making them pack better.
v. Displacement of air entrapped in the tissue.
vi. Denaturation of enzymes present in the food.

Blanching does not allow effective autoclaving and stops the activity of autolytic enzymes. For canned products, blanching removes gases, shrinks the food to correct fill weight in can, and offers preheating, which are very important to provide vacuum in can and proper sterilization.

Fruits are not blanched. All vegetables which cannot be eaten raw such as potatoes, greens, green beans, carrots, okra, turnip and cabbage should always be blanched while blanching is not needed for onions, leeks, tomatoes and sweet peppers.

Using sodium bicarbonate with blanching water preserves the green colour of vegetables by preventing the conversion of chlorophyll to pheophytin - unattractive brownish-green colour compound.

Methods of blanching: Blanching is a delicate processing step that requires careful monitoring of time, temperature and the other conditions. Effective blanching time necessary to inactivate enzymes is dependent on various factors such as type of food, method or type of heating, product size, temperature of heating medium etc. There are mainly two typical methods of blanching based on type of heating medium viz. hot water blanching and steam blanching. The former process involves temperatures below 100°C whereas the latter is carried out at temperatures above 100°C. A third type of blanching system exists which a combination of hot water and steam.

Blanching of green leafy vegetables especially spinach at boiling point causes loss of green colour but at lower temperature (77°C), it retains the natural green colour. At lower temperature, the enzyme chlorophyllase remains active for little time and converts chlorophyll to a phyllin, which retains green colour.

Hot water blanching: this method subjects clean food to hot water (85 to 100°C) until the enzymes are inactivated. Generally hot water blanching is done because of low capital costs and better energy efficiency. Disadvantages associated with hot water blanching include loss of water-soluble constituents, risk of contamination, higher cost of water, and method of effluent disposal.

Steam blanching: In this method, the food product is directly exposed to steam, which prevents the loss of food soluble solids (flavours, vitamins, acids, sugars etc.) to blanching medium as well as solves the problem of disposing blanching medium after processing. Advantages of steam blanching include reduced loss of water-soluble constituents, less volume of waste, easy to clean and sterilize. Some disadvantages of steam blanching include higher capital costs, uneven blanching, and low efficiency.

Blanchers with hot water and steam system: This type involves three step process viz. product on conveyer belts is exposed to steam followed by contact between food and hot water and finally immersion in hot water.

Efficacy of blanching:

Various types of enzymes such as lipoxygenase, polyphenolase, polygalacturonase, and chlorophyllase cause loss of food quality and therefore, must be inactivated. Two heat resistant plant enzymes such as catalase and peroxidase are used to evaluate blanching efficacy, as its inactivation requires appropriate time and temperature.

1.3.2 Cooking

Cooking is a process of heating in order to alter odour, flavour, and texture, and particularly to improve the digestibility of the food components. Cooking may take different forms of heating methods, which include:

Baking: Cooking in an oven with dry heat (100 – 232ºC)

Barbecuing: Direct heating over a glowing and smokeless wood fire

Boiling: Cooking in high temperature, usually water (100ºC). Cooking of rice, vegetables, meat, fish, beans, yam, potato, etc. at home is usually done by boiling the food with water and involves a temperature around 100°C.

Braising: Short frying followed by stewing
Broasting: Pressure frying
Broiling: Cooking with direct rays of heat.
Frying: Cooking in heated fat or oil (160-200^oC)
Grilling: Cooking with direct rays of heat.
Infrared Cooking: Cooking by infrared rays
Microwave Cooking: Cooking by microwaves - high frequency power.
Poaching: Cooking in a minimum volume of liquid at slightly below boiling temperature. **Roasting**: Cooking in open or closed vessel with just a little fat.
Sautéing: Tossing food in small quantity of oil (a kind of semi-shallow frying). Quick- fat-frying in small quantity of oil
Simmering: Cooking in water with gentle heating.
Steaming: Cooking in steam (at 100^oC)
Stewing: Simmering in a small amount of water in a closed container.

Self- Assessment Exercises

1. Define food sterilization
2. What is aseptic processing of food

1.4 Summary

Food products can be processed by different methods such as canning, Pasteurization, Sterilization, and Thermal Processing.
Foods can be Thermal processed using the methods of Pasteurization, Sterilization, Drying, and Dehydration. Foods can also be processed by canning, packaging aseptically and blanching. In the homes foods can be processed and preserved by cooking.

1.5 References/Further Readings

Walker, A.F (1990). Applied Human Nutrition. Aspen Publishers. 300 pages.

Bubel, M., Bubel, N and Art, P. (1991). Root Cellaring: Natural Cold Storage of Fruits and Vegetables. 2nd ed.

Coxe, A. H and Coxe, A. H (1997). The Great Book of Sausages. Overlook, 1992, 1997. Recipes, Instructions for Making 45 Varieties, and the History and Ingredients of 600 Types of Sausages.

Belitz, H.D., Grosch, W., Schieberle, P and M.M. Burghaghen, M.M (2004). Food Chemistry. Springer, 1071 pages

Hutkins, R (2006). Microbiology and Technology of Fermented Foods – A Modern Approach. Blackwell Publishing Professional, 488 pages

International Commission for Microbiological Specifications of Foods (ICMSF) (1996). Microorganisms in Foods - Characteristics of Microbial Pathogens – Springer. 1996. 524 pages

Marriot, N.G. and Gravani, R (2006). Principles of Food Sanitation, 5th Edition. Springer, 413 pages

Swaroop, K. R. and Giddaiah, R (2020). Societal Changes and Its Impact on Food Habits. *International Journal Of Scientific & Technology Research,9(2):246-271.*

Kumar, A (2019). Food Preservation: Traditional and Modern Techniques. *Acta Scientific Nutritional Health*, 3(12): 45 – 49

Lianou, A., *et al*., (2016). "Microbiological spoilage of beverages". In The Stability and Shelf Life of Food. (Subramanian, P. ed.) Second Edition Woodhead Publishing, India, 3-42.

Jay, J.M., Loessner, M.J. and Golden, D.A (2005). Modern Food Microbiology, 7th edition, Springer food science text series, 790 pages

Sancho-Madriz, M F (2003). "Preservation of Food". In Encyclopedia of Food Sciences and Nutrition. 2nd edition, Elsevier science Ltd publisher

Banti, M (2020). Food Adulteration and Some Methods of Detection, Review. *International Journal of Research Studies in Science, Engineering and Technology*, 7(4):9-19.

FSIS. (1996). FSIS Pre-HACCP Standard Sanitation Operating Procedures Reference Guide. Food Safety and Inspection Service, U.S. Department of Agriculture. 50 pages

Gardner, S. (1993). Consumers and Food Safety: A Food Industry Perspective. In Food, Nutrition, and Agriculture – Consumer Participation in Food Control.

Improving the Safety and Quality of Fresh Fruits and Vegetables: A Training Manual for Trainers. United Nations New York and Geneva, 2007 http://www.fao.org/docrep/v2890t/v2890t00.htm. 140 pages

Gould, W.A. and Gould, R.W (1993). Total Quality Assurance for the Food Industries. 2nd ed. CTI Publications, Baltimore, MD, USA.

1.6 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. Sterilization is the complete destruction of microorganisms including spores and requires heat treatment of 121°C for 15 minutes. But it has severe effect on heat sensitive nutrients and proteins through maillard reaction. The temperature and time required to sterilize the food varies with the type of food. Such high temperatures can be created by steam under pressure in steam pressure boilers/sterilizers.
2. The aseptic process involves placing a sterilized product into a sterilized package that is then sealed under sterile conditions. It involves the sterilization of liquid foods by rapidly heating them in tubular heat exchangers, followed by holding and cooling steps. Cold sterile products are then filled into sterilized cans and sealed in an atmosphere of superheated steam.

UNIT 2 FOOD PROCESSING OPERATIONS II: USE OF IRRADIATION AND MOISTURE REDUCTION

CONTENTS

2.1 INTRODUCTION

Food irradiation involves the use of either high-speed electron beams or high-energy radiation with wavelengths smaller than 200 nanometres, or 2000 angstroms (e.g. X rays, gamma rays and corpuscular radiations). These rays contain sufficient energy to break chemical bonds and ionize molecules that lie in their path. The two most common sources of high-energy radiation used in the food industry are cobalt-60 (60Co) and Caesium-137 (137Cs). At same level of energy, gamma rays have a greater penetrating power into foods than high-speed electrons.

Treatment of food with ionizing radiation is a useful tool for control of the presence of food borne non-spore-forming pathogenic bacteria and other microorganisms such as *Campylobacter*, *Escherichia coli* 0157:H7, *Listeria monocytogenes*, *Salmonella*, *Staphylococcus aureus* and parasitic organisms such as *Trichina*. These organisms cause diarrhea and in some cases, death.

The unit of absorbed dose of radiation by a material is denoted as the gray (Gy), one gray being equal to the absorption of one joule of energy by one kilogram of food. The energy possessed by an electron is called an electron volt (eV). One eV is the amount of kinetic energy gained by an electron as it accelerates through an electric potential difference of one volt. It is usually more convenient to use a larger unit such as mega electron volt (MeV), which is equal to one million electron volts.

Irradiation employs radiolysis - the splitting of water molecules into irreversible form thereby preserving the food because the water is unavailable for microbial and enzymatic activities.

The principle behind drying is that sufficient moisture is removed, which is essential for growth of microorganisms and for enzyme activity. Removal of moisture increases the storage life of the product due to reduced water activity. If the moisture content is reduced to 1 to 5 per cent then the product can be stored for more than a year. The processing should be done in such a way that the food value, natural flavour and characteristic cooking quality of the fresh foods are retained after drying. A good dried product on reconstitution with water should resemble the original product.

2.2 Learning Outcomes

By the end of this unit, you will be able to:

- Discuss food irradiation
- Write the positive and negative effects of food irradiation
- Discuss the processing of foods by moisture reduction
- Discuss the methods employed in achieving concentration of moist foods.

2.3 Biological Effects of Irradiation

The direct effects are due to the collision of radiation with atoms, resulting in an ejection of electrons from the atoms. The indirect effects are due to the formation of free radicals (unstable molecules carrying an extra electron) during the radiolysis of water molecules. The radiolysis of water molecules produces hydroxyl radicals that interact with the organic molecules present in foods. The products of these interactions cause many of the characteristics associated with the spoilage of food, such as off-flavours and off-odours.

2.3.1 Positive Effects of Irradiation

The bactericidal effect of ionizing radiation is due to damage of the bio-molecules of bacterial cells. The free radicals produced during irradiation may destroy or change the structure of cellular membranes. Radiation causes irreversible changes to the nucleic acid molecules (DNA and RNA) of bacterial cells and inhibits their growth. Pathogenic bacteria that are unable to Produce resistant endospores in foods such as poultry, meats, and seafood can be eliminated by radiation doses of 3 to 10 kilograys. If the dose of radiation is too low, then specialized enzymes repair the damaged DNA and life continues for them. If oxygen is present during irradiation, the bacteria are more readily damaged. Doses in the range of 0.2 to 0.36 kilograys are required to stop the reproduction of *Trichinella spiralis* in pork and require higher doses to eliminate it from the meat.

The dose of radiation used on food products is divided into three levels, namely:

i. Radurisation: This is the use of low doses of ionizing radiation adequate for reducing the numbers of spoilage organisms. It is a dose of 1 to 10 kilograys that is useful for targeting specific pathogens.

ii. Radicidation: The use of doses sufficient to reduce the numbers of specified viable non-sporing pathogens below detectable levels. It involves doses of less than 1 kilogray for extending shelf life and inhibiting sprouting.

iii. Radappertisation (commercial sterility): The treatment with doses of ionizing radiation sufficiently high for reducing the number of organisms below detectable levels. The range of dose is 20 to 30 kilograys and it is necessary to sterilize a food product.

2.3.2 Negative Effects

In the absence of oxygen, radiolysis of lipids causes cleavage of the inter-atomic bonds in the fat molecules, producing compounds such as carbon dioxide, alkanes, alkenes and aldehydes. Lipids are highly vulnerable to oxidation by free radicals - a process that yields peroxides, carbonyl compounds, alcohols and lactones. The consequent rancidity, resulting from the irradiation of high-fat foods is highly destructive to their sensory quality. To minimize such harmful effects, fatty foods must be vacuum-packaged and held at subfreezing temperatures during irradiation.

Proteins are not significantly degraded at the low doses of radiation employed in the food industry. For this reason irradiation does not inactivate enzymes involved in protein spoilage, as most enzymes survive doses of up to 10 kilograys. The large carbohydrate molecules that provide structure to foods are de-polymerized (broken down) by irradiation and this reduces the gelling power of the long chains of structural carbohydrates. However, in most foods other food constituents provide some protection against these deleterious effects. Vitamins A, E and B_1 (thiamine) are also sensitive to irradiation. The presence of air increases the nutritional losses of a food product during irradiation.

2.4 Safety Concerns

Based on the beneficial effects of irradiation on certain foods, several countries have permitted its use for specific purposes. These include the inhibition of sprouting of potatoes, onions and garlic; the extension of shelf life of strawberries, mangoes, pears, grapes, cherries, red currants, and cod and haddock fillets; as well as in the insect dis-infestation of pulses, peanuts, dried fruits, papayas, wheat and ground-wheat products.

The processing room used for irradiation of foods is lined with lead or thick concrete walls to prevent radiation from escaping. The energy source, such as a radioactive element or a machine source of electrons, is located inside the room and prior to the irradiation treatment, personnel vacate the room. The food to be irradiated is then conveyed by remote means into the room and exposed to the radiation source for a predetermined time. The time of exposure and the distance between the radiation source and the food material determines the irradiation treatment. After treatment, the irradiated food is conveyed out of the room, and the radioactive element is again lowered into the water reservoir.

2.4.1 Advantages of Irradiation

i. Any food can be irradiated at correct doses irrespective of the state of the food (solid, liquid, gases or liquids in frozen state).
ii. The Shapes and sizes of the food item are no barriers.
iii. Irradiation can be applied to materials other than food.
iv. It destroys parasites and enhances odour of essential oils.
v. It can be used to improve microbiological quality without significantly affecting the physical state and sensory qualities of the products.
vi. There is no risk of recontamination
vii. Most of the psychotropic microorganisms of importance to microbiological safety or keeping quality of chilled foods are relatively sensitive to radiation
viii. The incidence and contamination levels of pathogenic bacteria are usually low.
ix. It saves energy in production, distribution and marketing under ambient conditions.
xi. Irradiated foods last longer and can be accessible to a greater number of people at lower cost. xii. It enhances rural incomes since producers are able to sell a higher proportion of their product while it remains wholesome.
xiii. It improves food security especially for low income earners.

2.4.2 Disadvantages

i. If it is not used in the correct dose, it can lead to off-flavour.
ii. It can deposit carcinogenic matter in food that can cause malignant growth in the body. iii. It is dangerous and expensive to run.

Self- Assessment Exercises 1

1. State the advantages of irradiation
2. Discuss the Biological effects of Irradiaton

2.5 Preservation by Moisture Reduction

2.5.1 Drying and Dehydration

In Food Technology, drying refers to natural desiccation, such as spreading fruit on racks in the sun, and dehydration is drying by artificial means, such as a blast of hot air. Dehydration of food is an effective weapon against microbial attack, since the free water in food is essential for the proliferation of bacteria. Although the preservation of food by drying is an ancient practice, advances in Food Science and

Technology have created wholly new forms, such as compressed, freeze-dried foods that resume their original shape on rehydration.

The principle behind drying is that sufficient moisture is removed, which is essential for growth of microorganisms and for enzyme activity. Removal of moisture increases the storage life of the product due to reduced water activity. If the moisture content is reduced to 1 to 5 per cent then the product can be stored for more than a year. The processing should be done in such a way that the food value, natural flavour and characteristic cooking quality of the fresh material are retained after drying. A good dried product on reconstitution with water should resemble the original product.

Foodstuffs may be dried in air, superheated steam, vacuum, or inert gas or by direct application of heat. Air is the most generally used drying medium, because it is plentiful and convenient and permits gradual drying, allowing sufficient control to avoid overheating that might result in scorching and discoloration. Air may be used both to transport heat to the food being dried and to carry away liberated moisture vapour. The use of other gases requires special moisture recovery systems.

The proteins, fats and carbohydrates in dried foods are present in larger amounts per unit weight than in their fresh counterparts, and the nutrient value of most reconstituted or rehydrated foods is comparable to that of fresh items. The biological value of dried protein is dependent on the method of drying. Some vitamins are sensitive to the dehydration process, for example, in dried meats significant amounts of vitamin C and some B vitamins (riboflavin, thiamine, and niacin) are lost during dehydration. Dried eggs, meat, milk and vegetables are ordinarily packaged in tin or aluminum containers.

In freeze-drying, a high vacuum is maintained in a special cabinet containing frozen food until most of the moisture has sublimed. Removal of water offers excellent protection against the most common causes of food spoilage. Microorganisms cannot grow in a water-free environment, enzyme activity is absent, and most chemical reactions are greatly slowed down.

Vegetables, fruits, meat, fish, and some other high moisture foods may be dried to one-fifth of the original weight and about one-half of the original volume.

The disadvantages of this method of preservation include the time and labour involved in rehydrating the food before eating. Further, reconstituting the dried product may be difficult, because it absorbs only about two-thirds of its original water content; this phenomenon tends to make the texture tough and chewy.

Proteinous foods such as meat are of good quality only if freeze-dried. Liquid food is usually dehydrated by spraying it as fine droplets into a chamber of hot air (spray drier), or occasionally by pouring it over a drum internally heated by steam (drum drier).

In-package desiccants (drying agents) improve storage stability of dehydrated white potatoes, sweet potatoes, cabbage, carrots, beets and onions and give substantial protection against browning. Retention of ascorbic acid (vitamin C) is markedly improved by packaging at temperatures up to 49°C (120°F) using either nitrogen or air a the packaging gas.

Advantages of Drying and Dehydration

i. Low water activity, which aids food preservation.

ii. There is reduced weight compared to the initial weight of the food item, which eases packaging, storage and transportation.

iii. It allows for the production of certain convenience foods e.g. tea, coffee.

iv. Dehydration/ drying are cheaper than the other methods of preservation with less requirement of equipment.

v. Dried food products are simple to store and pack because of their low volume.

vi. It retains the size and shape of the original food.

vii. Dehydrated foods are less popular because of some undesirable changes in colour, taste and flavour during storage and distribution.

Factors in control of drying:

1. **Composition of raw materials:** Foods containing high amount of sugar or other solutes dry slowly.
2. **Size, shape and arrangement of stacking of produce:** the greater the surface area the greater the rate of drying.
3. **Temperature as well as humidity and velocity of air:** the greater the temperature differential between the product and the drying medium the faster it dries. Lowering the humidity of environment makes drying faster.
4. **Pressure**: the Lower the atmospheric pressure, the lower the temperature required to evaporate water.
5. **Heat transfer to surface (conductive, convective and radiative):** The fastest method of heat transfer is radiation consecutively followed by convection and conduction.

Types of Drying

Based on source of energy, drying can be done by two processes namely: natural drying and mechanical dehydration or artificial drying.

Natural drying takes place under the influence of sunlight and wind and is of three types namely: sun, solar and shade drying. In natural drying there is no control over temperature, air flow and humidity whereas in artificial drying, these conditions are well controlled.

Mechanical dehydration or artificial dehydration can be further classified into atmospheric and sub-atmospheric types based on the conditions employed in drying process. On the basis of mode of drying process, drying at atmospheric pressure conditions can be further divided into batch and continuous types.

Mechanical drying includes the methods of drying by:

(1) Heated air
(2) Direct contact with heated surface e.g. drum drying
(3) Application of energy from a radiating microwave or dielectric source.

Commercial dehydrators are generally large in size and various types of dehydrators can be used based on circulation of air as:

1. Natural
2. Forced draught

In natural draught method, the rising of heated air brings about drying of food. Examples include kiln, tower and cabinet driers. Forced draught employs currents of heated air that move across the food usually in tunnels. An alternative method is to move the food on a conveyor belt or trays through heated air. Examples include tunnel or belt drier. In forced draught drier, the temperature and humidity can be carefully controlled to get a good dehydrated product but are not in general use because of the cost.

Sun drying: Drying the food product under natural sunny conditions is called as sun drying. To practice sun drying of foods, hot days are desirable with minimum temperatures of 35°C with low humidity. Poor quality produce cannot be used for natural drying to achieve good quality dried product. The lower limit of moisture content by this method is approximately 15 per cent. Problems of contamination and intermittent drying are generally encountered with sun drying. It is only possible in areas of low humidity.

Solar drying: Solar driers generate high air temperature and low humidity which results in faster drying. Solar drier is faster than sun-drying and requires less drying area but cannot be used on cloudy days.

Three types of solar driers used are:

1. The absorption or hot box type: in this type of drier the product is directly heated by sun.
2. The indirect or convection driers: in this type of drier, the product is exposed to warm air heated by a solar absorber or heat exchanger.
3. Hybrid drier which is combination of first and second type.

Shade drying: This method is used for foods which lose their colour when exposed to direct sunlight for drying. Examples of foods dried using shade drying include herbs, green and red chilies, okra, beans, etc.

A home scale dehydrator or drier: this device consists of a small galvanized box with a dimension of 90x90x60 cm. The material to be heated is kept on trays and heating source can be a gas stove or any other source. The initial temperature of the dehydrator is usually is 43°C which is gradually increased to 60-66°C in the case of vegetables and 66-71°C for fruits. For a home scale drier 100-200 g of sulphur is required for 25 kg fruit. The time required for this type of drying is generally 30 minutes to 2 hours.

Oven drying: This is a kind of cabinet drier and a conventional oven drier with a thermostatic setting of 60°C is suitable for oven drying of fruits, vegetables, leathers, and meats.

Kiln drier (kiln evaporator): Kiln drier consists of two floors, food to be dried is spread on the top floor and the furnace is housed on the lower floor. In Kiln drier, heat is conveyed by a ventilator and it is used for large pieces of food.

Belt-trough drier: In Belt-trough drier, belt is in the form of a trough, which is made of metal mesh. Hot air is blown through the mesh and food pieces lying on the trough are dried in the process.

Spray drying: Spray drier is used to dry purees, low viscosity pastes, and liquids which can be atomized. The food is sprayed in a rapidly moving current of hot air and the dried product drops to the bottom of the drying chamber and is collected. Atomization into minute droplets results in drying in a matter of seconds with common inlet air temperature of about 200°C and a properly designed system quickly removes the dried particles from heated zones. This method of dehydration can produce exceptionally high quality with many highly heat sensitive materials including milk and coffee.

Microwave drying: This method uses microwaves to dry the food product.

Freeze drying: Foods in the pieces and liquids are dried by this method. Fruit juice concentrates are manufactured using freeze drying. The material is frozen on trays and then dried under vacuum. In vacuum drying, the material dries directly without passing through the intermediate liquid stage. The principle behind freeze drying is that under certain conditions of low vapour pressure, water can evaporate from ice without the ice melting. Freeze drying is used to dry sensitive and high value liquid as well as solid foods such as juices, coffee, strawberries, chicken dice, mushroom slices etc. The dried product is highly hygroscopic and reconstitutes readily. Taste, flavour and reconstitution property of fruit juice concentrates are excellent. This method is cost intensive. Freeze drying in combination with air drying is advantageous in reducing cost of drying. For example, vegetables pieces may be air dried to about 50 per cent moisture and then freeze dried down to 2-3 per cent moisture.

The disadvantages of freeze drying are that cooked flavour might result and it can also cause darkening of the food item.

2.5.2 Concentration of Moist Foods

This is the partial removal of water from a food item, giving rise to a syrup-like product. Food items such as syrups, evaporated milk, tomato ketchup and condensed soups are examples of concentrated food item. The methods employed in achieving concentration of moist food are:

i**. The kettle method:** This method involves the use of open kettles or pans. It is of benefit in foods where caramelization is desirable such as malt drink, stout, etc.

ii. **Flash method:** This process is commonly used for purees and it involves the application of superheated steam to the food items in steam jackets.
iii. **Film method:** This involves pumping the food into a heated vertical cylinder to produce a film of the food which gets dry fast.
iv. **Vacuum method:** This is applied to heat sensitive foods.
v. **Freeze concentration method:** This involves the removal of frozen water from food items via sublimation.
vi. **Ultra-filtration and reversed osmosis:** This process involves the use of a selectively permeable membrane, which filters and leaves the macromolecules.

Self- Assessment Exercises 2

1. State the advantages of drying and dehyradtion
2. Outline the two types of drying

2.6 Summary

Food irradiation is safer than fumigation of Foods but nonetheless it has advantages and disadvantages. Food Preservation and processing can also be achieved either by reduction in moisture contents or concentration of moist foods.
Irradiation of foods is a useful tool for control of the presence of food borne non-spore-forming pathogenic bacteria and microorganisms. There are serious biological effects of food irradiation, some of whichh are advantageous while others are undesirable. Preservation of foods is achieved by moisture reduction and concentration of msoist foods.

2.7 References/Further Readings

Walker, A.F (1990). Applied Human Nutrition. Aspen Publishers. 300 pages.

Bubel, M., Bubel, N and Art, P. (1991). Root Cellaring: Natural Cold Storage of Fruits and Vegetables. 2nd ed.

Coxe, A. H and Coxe, A. H (1997). The Great Book of Sausages. Overlook, 1992, 1997. Recipes, Instructions for Making 45 Varieties, and the History and Ingredients of 600 Types of Sausages.

Belitz, H.D., Grosch, W., Schieberle, P and M.M. Burghaghen, M.M (2004). Food Chemistry. Springer, 1071 pages

Hutkins, R (2006). Microbiology and Technology of Fermented Foods – A Modern Approach. Blackwell Publishing Professional, 488 pages

International Commission for Microbiological Specifications of Foods (ICMSF) (1996). Microorganisms in Foods - Characteristics of Microbial Pathogens – Springer. 1996. 524 pages

Marriot, N.G. and Gravani, R (2006). Principles of Food Sanitation, 5th Edition. Springer, 413 pages

Swaroop, K. R. and Giddaiah, R (2020). Societal Changes and Its Impact on Food Habits. *International Journal Of Scientific & Technology Research,9(2):246-271.*

Kumar, A (2019). Food Preservation: Traditional and Modern Techniques. *Acta Scientific Nutritional Health*, 3(12): 45 – 49

Lianou, A., *et al*., (2016). "Microbiological spoilage of beverages". In The Stability and Shelf Life of Food. (Subramanian, P. ed.) Second Edition Woodhead Publishing, India, 3-42.

Jay, J.M., Loessner, M.J. and Golden, D.A (2005). Modern Food Microbiology, 7th edition, Springer food science text series, 790 pages

Sancho-Madriz, M F (2003). "Preservation of Food". In Encyclopedia of Food Sciences and Nutrition. 2nd edition, Elsevier science Ltd publisher

Banti, M (2020). Food Adulteration and Some Methods of Detection, Review. *International Journal of Research Studies in Science, Engineering and Technology*, 7(4):9-19.
FSIS. (1996). FSIS Pre-HACCP Standard Sanitation Operating Procedures Reference Guide. Food Safety and Inspection Service, U.S. Department of Agriculture. 50 pages

Gardner, S. (1993). Consumers and Food Safety: A Food Industry Perspective. In Food, Nutrition, and Agriculture – Consumer Participation in Food Control.

Improving the Safety and Quality of Fresh Fruits and Vegetables: A Training Manual for Trainers. United Nations New York and Geneva, 2007 http://www.fao.org/docrep/v2890t/v2890t00.htm. 140 pages

Gould, W.A. and Gould, R.W (1993). Total Quality Assurance for the Food Industries. 2nd ed. CTI Publications, Baltimore, MD, USA.
Satin, Morton (1996). *Food Irradiation: A Guidebook,* 2nd edition. Lancaster, PA: Technomic Publishing.

FDA. (1998). Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables. http://www.cfsan.fda.gov/~dms/ prodguid.html.

FDA. (2000). Food Standards. Available via the Internet at www.fda.gov/opacom/morechoices/smallbusiness/blubook/ foodstds.htm.

FDA. (2001). FDA Publishes Final Rule to Increase Safety of Fruit and Vegetable Juices. http://www.fda.gov/bbs/topics/NEWS/2001/NEW00749.html

2.8 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. Advantages of Irradiation

i. Any food can be irradiated at correct doses irrespective of the state of the food (solid, liquid, gases or liquids in frozen state).

ii. The Shapes and sizes of the food item are no barriers.

iii. Irradiation can be applied to materials other than food.

iv. It destroys parasites and enhances odour of essential oils.

v. It can be used to improve microbiological quality without significantly affecting the physical state and sensory qualities of the products.

vi. There is no risk of recontamination

vii. Most of the psychotropic microorganisms of importance to microbiological safety or keeping quality of chilled foods are relatively sensitive to radiation

viii. The incidence and contamination levels of pathogenic bacteria are usually low.

ix. It saves energy in production, distribution and marketing under ambient conditions.

xi. Irradiated foods last longer and can be accessible to a greater number of people at lower cost. xii. It enhances rural incomes since producers are able to sell a higher proportion of their product while it remains wholesome.

xiii. It improves food security especially for low income earners.

2. **Biological Effects of Irradiation**

The direct effects are due to the collision of radiation with atoms, resulting in an ejection of electrons from the atoms. The indirect effects are due to the formation of free radicals (unstable molecules carrying an extra electron) during the radiolysis of water molecules. The radiolysis of water molecules produces hydroxyl radicals that interact with the organic molecules present in foods. The products of these interactions cause many of the characteristics associated with the spoilage of food, such as off-flavours and off-odours.

Answers to Self-Assessment Exercises 2

1. Advantages of Drying and Dehydration are:

i. Low water activity, which aids food preservation.

ii. There is reduced weight compared to the initial weight of the food item, which eases packaging, storage and transportation.

iii. It allows for the production of certain convenience foods e.g. tea, coffee.

iv. Dehydration/ drying are cheaper than the other methods of preservation with less requirement of equipment.

v. Dried food products are simple to store and pack because of their low volume.

vi. It retains the size and shape of the original food.

vii. Dehydrated foods are less popular because of some undesirable changes in colour, taste and flavour during storage and distribution.

2. Natural drying and mechanical dehydration or artificial drying.

UNIT 3 FOOD PROCESSING OPERATIONS III: USE OF ADDITIVES, MODIFIED ATMOSPHERE AND FERMENTATION

CONTENTS

3.1 INTRODUCTION

Food Additives are compounds that are added to foods as an aid to processing, improving the keeping qualities, flavour, colour, texture, appearance and stability of the food. Vitamins, minerals and other nutrients added to fortify or enrich the food are generally excluded from the definition of additives, as well as herbs, spices, salt and yeast or protein hydrolysates commonly used to enhance flavour.

Preservatives are the chemical agents which serve to retard, hinder or mask undesirable changes in food this is achieved by retarding, inhibiting or arresting the activities of microorganisms such as fermentation, acidification and decomposition of food or of masking any of the evidence of putrefaction but it does not include salt, sugar, vinegar, glycerol, alcohol, spices, essential oils etc.

Preservatives may be anti-microbial preservatives, which inhibit the growth of bacteria and fungi, or antioxidants such as oxygen absorbers, which inhibit the oxidation of food constituents. Common anti-microbial preservatives include calcium propionate, sodium nitrate, sodium nitrite and sulfites (sulfur dioxide, sodium bisulphite, potassium hydrogen sulphite, etc.) and ethylenediamine tetra acetic acid (EDTA). Antioxidants include butylated hydroxy anisole (BHA) and butylated hydroxy toluene (BHT).

Sulphur dioxide and benzoic acid are among the major preservatives used in the food processing industry.

Chemical preservatives are food additives specifically added to prevent the deterioration or decomposition of a food. Preservation of foods by the chemicals is affected by interfering with the cell membrane of the microorganism, their enzyme activity and genetic mechanism; and by acting as antioxidants.

Where laboratory testing has shown that high intake of an additive has adverse effects on experimental animals, the amount that may be used is controlled by law to ensure that the total intake from all foods in a daily diet is within a safe range. This acceptable daily intake (ADI) is usually one- hundredth of the highest dose that has no detectable effect in laboratory tests. Compounds for which no adverse effects can be detected, even using extremely high levels of intake, are classified as "ADI not determined", and may be used without any limitation, although the intensity of colour and flavour will usually limit the amount that is used. Additives are classified by their function and it includes:

Class I preservatives: This class I is considered to be relatively safe to humans and includes the use of sugar, salt, spices, acetic acid and alcohol.

Class II preservatives: This is considered to be relatively safe to humans, but within the permissible doses prescribed by the food regulatory bodies of the country because higher concentrations can be a health hazard and they includes the use of benzoic acid, sulfur dioxide, nitrates and nitrites and a variety of neutralizers, firming agents and bleaching agents.

Permitted usage levels of chemical preservatives in foods

Foods	**Chemical preservative**	**Concentration (ppm)**
i. Nectars, ready to serve beverages in bottles/pouches selling through dispenser. ii. Fruit juice concentrates with preservatives for conversion in juices, nectars for ready to serve beverages in bottles/ pouches selling	Sorbic acid and its salts (calculated as sorbic acid)	50 100 200

through dispensers. iii. Fruit juices (tin, bottles or pouches) iv. Jams, jellies, marmalades, preserve, crystallized glazed or candied fruits including candied peels fruit bars		
i. Ready to serve beverages. ii. Jam, marmalade, preserved canned cherry and fruit jelly. iii. Pickles and chutneys made from fruits or vegetables. iv. Squashes, crushes fruit syrups, cordials, fruit juices and barley water or to be used after dilution; Syrups and sherbets. v. Tomato and other sauces; Tomato puree and paste	Benzoic acid and its salts	120 200 250 600 750
i. Jam, marmalade, preserved canned cherry and fruit jelly. ii. Crystallized glace or cured fruit (including candied peel) iii. Squashes, crushes fruit syrups, cordials, fruit juices and barley water or to be used after dilution; Syrups and sherbets; Fruit and fruit pulp. iv. Dehydrated vegetables	Sulphur dioxide	40 150 350 2000
Pickled meat	Sodium and / or Potassium nitrite expressed as Sodium nitrite	200
Fermented meat, dairy and vegetable products, sauces and dressings, drinks.	Lactic acid	No limit
Fruit juices; jams; other sugar preserves	Citric acid	No limit
Vegetable pickles; other vegetable sauces, chutney	Acetic acid	No limit

3.2 Learning Outcomes

By the end of this unit the student should be able to:

- Analyse "food additive"
- Discuss the additives according to functions
- Discuss the use of modified technology to improve qualities of foods
- Analyse the types of fermentation of foods.

3.3 Types of Additives

3.3.1 Colourants

These refer to a range of organic compounds either synthetic chemicals or naturally occurring plant pigments, namely: chlorophyll, carotenoids and anthocyanins that may be added to foods to enhance the colour. When a desirable food process leads to a loss of colour from the food, or a new product looks unduly insipid, the processor wisely takes steps to make it more attractive through the use of food grade colours. Some mineral salts can also be used as colours salts of calcium and iron which enhance the nutritional value of the food as well as its colour.

3.3.2 Preservatives

The Food and Drug Administration defines a chemical preservative as "any chemical that when added to food, tends to prevent or retard deterioration, but does not include common salt, sugars, vinegars, spices or oils extracted from spices, substances added to food by direct exposure thereof to wood smoke or chemicals applied for their respective insecticidal or herbicidal properties".

The ideal chemical preservative must be able to inhibit the growth of moulds, yeasts and bacteria. It must be non-toxic to test animals and ultimately to humans. It should be capable of been metabolized by the body and not subject to further detoxification procedure in the liver. There should not be a residue build-up in fatty tissue. Ideally, it should be water-soluble because if it is fat-soluble, it might be unavailable for antimicrobial action, since micro-organisms grow in the aqueous phase. It should be stable in the food product and not react with other additives or natural components of food. It should exhibit no taste, odour or colour. It should be cheap and be able to pay for itself by reducing spoilage and minimizing food borne illness.

Preservatives are used to protect foods against the growth of micro-organisms that might cause spoilage or food poisoning, and so increase the safe storage life of the product. Such compounds include sorbic and benzoic acids and their salts, sulphur dioxide and its salts, as well as nitrites and nitrates used in pickling salts. The following is a review of commonly used preservatives.

a. Benzoates

The optimum pH range for antimicrobial activity by benzoates is 2.5 – 4.0, which is lower than that for sorbate or propionate. Sodium benzoate has activity against yeast, mould and bacteria but is not usually recommended for bacterial control because of its decreased activity above pH 4.5, where bacteria are the greatest problem. The lower pH range makes benzoates well suited for the preservation of foods that are acidic or readily acidified, such as carbonated beverages, fruit juices and pickles. FDA regulations generally recognize benzoates as safe for use in foods with a maximum level of 0.1%. Benzoates are cheap compared to other antimicrobial additives.

b. Parabens

1. The antimicrobial property of parabens is directly proportional to its chain length but solubility decreases with increase in chain length. Usually, a combination of methyl and propyl esters are often used. The parabens are not water-soluble and are most active against gram-negative bacteria. The parabens are more costly than other preservatives. The methyl and propyl ester are considered GRAS "generally regarded as safe"

with a maximum total use level of 0.1%. They are used in cakes and fillings, soft drinks, fruit juices and salads, and artificially sweetened jams and jellies. A maximum level of 12 ppm heptyl ester is used in beer.

c. Propionates

Propionates were among the first monocarboxylic fatty acids to be used as an antimicrobial agent in foods. Propionates have good antimicrobial activity against moulds but little against yeasts and bacteria. They are considered as GRAS for use in foods and have no upper limits except in products like bread, rolls and cheese. Calcium and sodium propionate are equally effective, but the calcium salt is used in breads and rolls because of the enrichment contribution of calcium. The sodium salt is used in chemically leavened products because the calcium ion interferes with the leavening action.

d. Sorbates

Sorbic acid is slightly soluble in water but potassium salt is very water-soluble (up to 139g/100ml at 25°C). The optimum pH range of effectiveness extends up to pH 6.5, higher than the upper range of benzoates and propionates but below that of parabens. Sorbates are used to preserve cheese products, baked foods, beverages, syrups, fruit juices, wines, jellies, jams, salads, pickles, margarine and dried sausages. Sorbates are considered as GRAS and have been used traditionally as antifungal agent in foods and food wrappers to control yeasts and moulds. Being a fatty acid, sorbates are metabolised by the body to carbon dioxide and water. Sorbates are cheap and are usually used in lower quantities than the cheaper benzoates and propionates in the higher-pH products to achieve the desired effect.

e. Acetates

Some derivatives of acetic acid such as monochloroacetic acid, peracetic acid, dehydroacetic acid and sodium diacetate have been recommended as preservatives, but not all are approved by the FDA. Dehydroacetic acid has been used to impregnate wrappers for cheese to inhibit the growth of moulds and as a temporary preservative for squash. Acetic acid in the form of vinegar is used in mayonnaise pickles, catsup and pickled sausages. Acetic acid is more effective against yeast and bacteria than moulds, and its effectiveness increases with a decrease in pH. Sodium diacetate has been used in cheese spreads, malt syrups and as treatment for wrappers used on butter.

f. Sulphites

Sulphurous acid, the active antimicrobial compound is formed by sulphur dioxide, sulphite salts, bisulphate salts and metabisulphite salts in aqueous solutions. The effectiveness of sulphurous acid is enhanced at low pH values. The fumes of burning sulphur are used to treat most light- coloured dehydrated fruits, while dehydrated vegetable are exposed to a spray of neutral bisulphite and sulphites before drying. Sulphur dioxide has also been used in syrups, fruit juices and wine making. sulphites can also be used on meat and fish.

Sulphites are also used to prevent enzymatic and non-enzymatic changes or discolouration in some foods in addition to its antimicrobial action. They are most effective against yeasts, moulds and bacteria. However, current levels are limited because at about 500 ppm the taste becomes noticeable. SO_2 and several sulphite salts are considered GRAS, but they may not be used in foods which have substantial amounts of thiamine. Bisuphites also degrade aflatoxin B_1 and G_1 in addition to its antimicrobial action.

g. Nitrites and Nitrates

Combinations of nitrite and nitrate salts have been used in curing solutions and curing mixtures for meats. Nitrites decompose to nitric acid, which forms nitrosomyoglobin when it reacts with the heme pigments in meats and thereby forms a stable red colour. Nitrates only act as a reservoir for nitrite and its use is being restricted. Nitrites can react with secondary and tertiary amines to form nitrosamines, which are known to be carcinogenic. The problem of possible carcinogenic nitrosamines appears to be greatest in cured meat from the back or sides of pig (bacon). The extended future for the use of nitrites in foods is therefore questionable and at least controversial. They are currently added in the form of sodium nitrite, potassium nitrite, sodium nitrate, or potassium nitrate. Studies have demonstrated the inhibitory property of nitrites toward *Clostridium botulinum* in meat products, particularly in bacon and canned or processed hams.

3.3.3 Smoke

The smoking of foods usually has two main purposes, adding desired flavours and preserving. Other desirable effect that may result includes:

improvement in the colour of the inside of meat and in the finish, or "gloss" of the outside and a tenderising action on meats. Normally, smoke is obtained from burning wood, preferably a hard wood like hickory, but may also be generated from burning corn cobs or other materials or woods like apple, oak, maple, beech, birch, walnut and mahogany.

Preservative action is provided by bactericidal chemicals in the smoke such as formaldehyde, guaiacol (2-methoxyphenol), and creosote, which has limited bactericidal and antioxidant action and by the dehydration that occurs in the smokehouse. Wood smoke contains a large number of volatile compounds that differ in their bacteriostatic and bactericidal effect. Wood smoke is more effective against vegetative cells than against bacterial spores and the rate of germicidal action of the smoke increase with its concentration and the temperature and varies with the kind of wood employed. The residual effect of the smoke in the food has been reported to be greater against bacteria than against moulds. The application of "liquid smoke", a solution of chemicals similar to those in wood smoke, to the outside of foods has little or no preservatives effect although it contributes to flavour.

3.3.4 Sugar and Salt

Sugar and Salt tend to tie up moisture and thus have adverse effect on micro-organisms. The adverse effects of Salts on foods are:

1. It causes high osmotic pressure and hence plasmolysis of cells; however, the percentage of salt necessary to inhibit growth or harm the cell varies with the micro-organism.
2. It dehydrates foods by drawing out and tying up moisture as it dehydrates microbial cells.
3. It ionizes to yield the chlorine ion which is harmful to organisms
4. It reduces the solubility of oxygen in the moisture
5. It sensitizes the cell against carbon dioxide
6. It interferes with the action of proteolytic enzymes.

Sugars like glucose or sucrose are effective as preservatives due to their osmotic effect and ability to make water unavailable to organisms. Examples of foods preserved by high sugar concentrations are sweetened condensed milk, fruits in syrups, jellies and candies.

3.3.5 Formaldehyde

The addition of formaldehyde to foods is not permitted, except, as a minor constituent of wood smoke. Formaldehyde is effective against moulds, bacteria and viruses and can be used where its poisonous nature and irritating properties are not objectionable. It is useful in the treatment of walls, shelves, floors, etc to eliminate moulds and their spores.

3.3.6 Antioxidants

Antioxidants are used to prevent rancidity in fatty foods and to protect the fat- soluble vitamins against damage by oxidation. Synthetic antioxidants include esters of gallic acid, tertiary butylhydroquinone

(TBHQ), butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA). BHA and BHT are not permitted in baby foods while L-Ascorbic acid is preferred for moist foods, such as meat, bakery products and beer. Vitamins C and E are also used as antioxidants; they clearly enhance the nutritional value of the food to which they are added. Some spices have value as antioxidants, but their main function is flavour enhancement just like the additive monosodium glutamate.

3.3.7 Acidity Regulators (Acidulants)

Acidulants act to reduce the pH, minimize microbial growth and enhance the effect of the weak acid preservatives. Alkalis, including sodium, potassium, calcium, and magnesium hydroxides, may be used to neutralize excess acidity in foods. Acids and their salts are used as flavourings and also to control the pH of foods. Acetic acid, lactic acid , propionic, malic and fumaric acids, also have valuable antimicrobial action, and may, in addition, be classified as preservatives. Others, including ascorbic (vitamin C), citric, tartaric, phosphoric, hydrochloric, sulphuric acids and their salts, as well as carbon dioxide and carbonates or bicarbonates may be used either as buffers or for special purposes, including acting as emulsifying agents, raising agents or anticaking agents.

3.3.8 Emulsifiers and Stabilizers

An emulsifier is a substance which aids the formation of a stable mixture of two immiscible substances such as fat and water. A stabilizer helps to maintain an emulsion when it is formed. The stabilizer may have the same basic characteristic with an emulsifier, or it may serve to thicken one or more participant in the emulsion, or make it more viscous and hence less likely to separate into its components. Additives in this group are used to enable oils and fats to mix with water and to form smooth emulsions (example margarine and mayonnaise), to give a smooth creamy texture to foods, and to slow the staling of baked goods. A variety of plant gums, including alginates, agar, guar gum, and carob gum, may make a useful contribution to the intake of non- starch polysaccharide (dietary fibre), as may pectins and the various cellulose derivatives that are widely used. Lecithin and a variety of salts and esters of fatty acids are also emulsifying agents.

3.3.9 Anticaking Agents

These are anhydrous substances that can pick up moisture without themselves becoming wet. In other words, they immobilize moisture coming in contact with a food material. They are added to particulate products, such as dry mixes, to prevent the particles from clumping together and so keeps the product free flowing. Anticaking agents are used to ensure that powders such as flour or salt remain free flowing. compounds that are used as anticaking agents include bone meal, polyphosphates, silicates, stearates, gluconates, salts of long chain fatty acids (such as myristic, palmitic and stearic).

3.3.10 Humectants

They are required to keep certain food products moist as in bread and cakes. Humectants pass any incoming moisture into the product to compensate for losses due to natural drying. All humectants are hygroscopic in nature. Commonly used humectants include glycerol, sorbitol and propan-1, 2-diol.

3.3.11 Sequestrants

Metals like copper and iron can act as pro-oxidant catalyst and therefore need to be immobilized. Sequestrants are compounds added to do just that and they include EDTA, phosphates, tribasic citric acid, tartaric acid and its salts.

3.3.12 Flavouring Agents

These include sweeteners, some fruit acids, natural extracts of fruits and herbs, and synthetic compounds designed to mimic natural flavours. A number of compounds such as glutamic acid and its salts (especially monosodium glutamate), and nucleic acid derivatives are used to enhance the flavour of foods, without giving any particular flavour of their own.

Self- Assessment Exercises 1

1. State the properties of preservatives
2. Discuss "Anticaking Agent"

3.4 Use of Modified Atmospheres

The normal composition of air is 20% oxygen (O_2), 79% nitrogen (N_2) and 1% carbon dioxide (CO_2). A modified atmosphere (MA) is one in which the normal composition of air around a food material is changed or "modified" at the point of packing. This modification usually results in a reduction of the O_2 content of air while increasing the level of CO_2 and N_2. A controlled atmosphere (CA) is a process whereby the gaseous environment is modified to a desired level and controlled at that level, with strict limits, throughout storage and usually applied to bulk storage products. A modified atmosphere applies to food packaged in small convenient retail units in which the gaseous atmosphere is modified or changed at the point of packing.

3.4.1 Vacuum Packaging

This is the most common method of modifying the internal package environment and is used extensively by the meat industry to extend the shelf life and keeping quality of fresh meat. The product is placed in a film of low oxygen permeability, air is evacuated and the package is sealed. Under conditions of a good vacuum, headspace O_2 is reduced to <1% while CO_2, produced from tissue and microbial respiration, eventually increases to 10-20% within the package headspace. These conditions, i.e. low O_2 and elevated CO_2 levels, help extend the shelf life

of meat by inhibiting growth of normal aerobic meat spoilage microorganisms particularly *Pseudomonas* and *Altermonas* species.
The shelf life of a vacuum packaged meat depends on a number of inter-related factors; specifically the microbiological quality and pH of meat at time of packing; packaging film permeability, package integrity and storage temperature. The main disadvantage of vacuum packaging from a commercial viewpoint is that the depletion of oxygen, coupled with the low oxygen permeability of the packaging film, results in a change of meat colour from red to brown. Vacuum packaging cannot be used on soft products such as pizza, pasta or baked products.

3.4.2 Gas Packaging

Gas Packaging involves packaging of product under an atmosphere of various gases such as CO_2, N_2, O_2 and sometimes CO but the most commonly used and perhaps the most effective is CO_2 with or without other gases. For example, with meat O_2 is necessary for the bright red colour or "bloom" which is associated with good quality meat but O_2 also promotes microbial growth. Carbon dioxide is a bacteriostatic agent, but it will discolour fresh meat. The problem of balancing these two separate effects can be overcome by using a mixture of gas incorporating CO_2, O_2 and N_2. The N_2 is needed to prevent the packaging film collapsing around the product as CO_2 dissolves the meat.
The major advantages of gas packaging are: increased shelf life, increased market area, reduction in production and storage costs, reduction in use of inhibitors, improved presentation, fresh appearance, clear view of product and easy separation of slices. Some of its disadvantages include high initial cost of packaging equipment, films, etc; discolouration of meat pigments, leakage, and fermentation by CO2 resistant microorganisms, swelling and potential growth of organisms of public health significance

3.4.3 Oxygen Absorbants

Oxygen absorbants consist of iron oxide packaged in small sachets like a desiccant (sold under the trade name "ageless") and come in a variety of sizes that absorb 20 – 2000 cc of oxygen. When used in conjunction with a film of low oxygen permeability, the headspace O_2 is reduced to less than 0.05% within hours in the packaged product and remains at this level for the duration of the storage period. Oxygen absorbants have been widely used in Japan to extend the mould-free shelf life of bread, pizza crusts and cakes as well as prevent oxidation of fats in potato chips, dried fish, beef jerky, semi-moist cookies and chocolates.

3.4.4 Ethanol Vapour Generators

Ethanol is widely used as a germicidal agent but few studies have evaluated ethanol as a food preservative. A novel and innovative method of generating ethanol vapour, is through the use of ethanol vapour generators, sold under the trade name "ethicap". Ethicap comprises of a paper/ethyl vinyl acetate sachet containing food grade ethanol adsorbed onto a fine silicon dioxide powder. When a food is packed with a sachet of ethicap, moisture is absorbed from the food and ethanol vapour is released from encapsulation and permeates the package headspace. Ethanol vapours are extensively used in Japan to extend the shelf life of high moisture baked products.

3.5 Fermentation and Pickling

Fermentation is a process of anaerobic or partial anaerobic oxidation during which enzymes from microorganisms or the food material break down carbohydrates or carbohydrate-like material into simpler substances. It may also be defined as an ATP generating metabolic process in which organic compounds serve both as electron donors and as electron acceptors. Fermentation may be separated into that caused by microorganisms and those influenced by enzymes. However, only those products involving the deliberate fermentative growth of microorganisms are described as being fermented. Products whose manufacture primarily involves the activity of indigenous or added enzymes are better referred to as being enzyme hydrolyzed. In cases where the hydrolysis is purely due to indigenous enzymes, this will be properly described as autolysis.

Normally, fermentation results in the breakdown of complex organic substances into simpler ones through catalysis. For example, by the action of diastase, zymase, and invertase, starch is broken down (hydrolyzed) into complex sugars, then simple sugars and finally alcohol. Fermentation is employed in the processing of some food items like burukutu, bread, milk products, matured palm wine, beer etc.

It seems quite contradictory that microorganisms and enzymes, which are known to be responsible for food spoilage and deterioration, are also used for food preservation. Microorganisms and enzymes are able to achieve this due to the following reasons:

The environment of the food item is saturated with the fermenting organisms which lower the pH and prevent entry of other microorganisms. As the pH is reduced, preservation is ensured. Macromolecules in the food would have been broken down into macromolecules which can no longer be attacked by microorganisms. They produce alcohols, acids etc which are capable of preserving the food. The keeping quality of alcoholic beverages depends on the percentage of ethanol produced. The higher the percentage produced, the longer the shelf life.

The action of certain bacteria on undigested carbohydrates causes fermentation in the human intestine producing gases such as hydrogen sulphide and carbon dioxide in amounts large enough to cause distension and pain. Acids such as lactic acid and ethanoic acid may also form in the intestines of infants, causing diarrhoea.

Pickling deals with preservation of food materials, especially vegetables, in brine, vinegar and mustard. The process results in absorption of salts, which in turn, result in removal of water from the flesh to a level that impedes microbial growth and enzyme activities. Fresh fruits and vegetables soften after 24 hours in a watery solution and begin a slow, mixed fermentation-putrefaction process. The addition of salt suppresses undesirable microbial activity, creating a favourable environment for the desired fermentation. Pickling may therefore be used to preserve most green vegetables and fruit.

Meat may be preserved by dry curing or with a pickling solution. The ingredients used in curing and pickling are sodium nitrate, sodium nitrite, sodium chloride, sugar, and citric acid or vinegar.

Various methods are used: the meat may be mixed with dry ingredients; it may be soaked in pickling solution; pickling solution may be pumped or injected into the flesh; or a combination of these methods may be used. Curing may also be combined with smoking. Smoke acts as a dehydrating agent and coats the meat surfaces with various chemicals, including small amounts of formaldehyde.

Fermented foods and pickled products require protection against moulds which metabolize the acid developed and allow the advance of other microorganisms. Fermented and pickled food products placed in cool storage remain stable for several months. Longer storage periods demand more complete protection (such as canning). Nutrient retention in fermented and pickled products is about equal to retention for products preserved by other methods or increased because of the presence of yeasts.

3.5.1 Types of Fermentation

An important type of fermentation is alcoholic fermentation, in which the action of zymase secreted by yeast converts simple sugars, such as glucose and fructose, into ethyl alcohol and carbon (iv) oxide. Many other kinds of fermentation occur naturally, as in the formation of butanoic acid when butter becomes rancid and of ethanoic (acetic) acid when wine turns to vinegar.

Alcoholic Fermentation

Alcoholic fermentation involves the use of yeast to breakdown glucose into alcohol and carbon (iv) oxide. This step is involved in the alcoholic fermentation of starchy foods by species of *Saccharomyces* (*carlsbergensis* or *cerevisiae*). It is applied in the brewing industry where beer and similar cereal beverages that undergo fermentation are produced.

Acetic Acid Fermentation

This involves the conversion of ethanol into acetic acid by *Acetobacter*. This step is involved in the souring of wine.

Lactic Acid Fermentation

Lactic acid is usually prepared by fermentation of lactose, starch, cane sugar or whey. This acid, generated in milk by fermentation of lactose, causes the souring of milk. The lactic acid bacteria, as presently constituted, consists of the following four genera *Lactobacillus*, *Leuconostoc*, *Pediococcus* and *Streptococcus*. They all share the property of producing lactic acid from hexose sugars. Lactic acid is used in preparing cheese, sauerkraut, soft drinks, and other food products. In this type of fermentation, glucose is converted to lactic acid by *Lactobacillus*. Lactic acid fermentation is employed in dairy for the production of sour milk products.

Self- Assessment Exercises 2

1. List the types of fermentation.

2. What are the advantages of Vacuum packaging?

3.6 Summary

The food industries employ many methods to improve the qualities of their products including: the use of additives to improve colour, flavour and shelf life, the use of modified atmosphere to create conducive environment for the non-growth of microorganisms and the use of various preservatives to prevent spoilage

Additives are used extensively in the food industry to improve colour, flavour and preservation.

Modern biotechnology can be applied in (a) fermentation (b) vacuum packaging and (c) gas packaging to improve the shelf life and qualities of meat and beverages.

3.7 References/Further Readings

Gardner, S. (1993). Consumers and Food Safety: A Food Industry Perspective. In Food, Nutrition, and Agriculture – Consumer Participation in Food Control.

Improving the Safety and Quality of Fresh Fruits and Vegetables: A Training Manual for Trainers. United Nations New York and Geneva, 2007 http://www.fao.org/docrep/v2890t/v2890t00.htm. 140 pages

USDA. (2000). Fruit and Vegetable Programs. www.ams.usda.gov/fv/fvstand.htm

U.S. EPA. (2001). Guidance for Preparing Standard Operating Procedures. Office of Environmental Information, U.S. Environmental Protection Agency. EPA/240/B-01/004. http://www.epa.gov/quality1/qs- docs/g6-final.pdf

van Reeuwijk, L.P. (1998). Guidelines for quality management in soil and plant laboratories. FAO, Rome. Publication #M-90. http://www.fao.org/docrep/w7295e/w7295e00.htm

Wilson, L.G., Boyette, M.D., and Estes, E.A. (1995). Postharvest handling and cooling of fresh fruits, vegetables, and flowers for small farms. Part I: Quality maintenance. Horticultural Information Leaflet #800, North Carolina Cooperative Extension Service. http://ces.ncsu.edu/depts/hort/hil/hil-800.html

ASQ. (2000). ISO 9000 Standards for Quality. Amer. Soc. Qual. http://www.iso-9000-2000.com

Boutrif, E. and Bessy, C. (1999). Basic Approaches to consumer Protection – FAO/WHO Model Food Act – Control Procedures. Presented at Conference on International Food Trade – Beyond 2000: Science-based Decisions, Harmonization, Equivalence, and Mutual Recognition, Melbourne, Australia October 11-15.

Codex. (2000). Codex Committee on Fresh Fruits and Vegetables. http://www.codexalimentarius.net

3.8 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. The ideal chemical preservative must be able to inhibit the growth of moulds, yeasts and bacteria.
2. It must be non-toxic to test animals and ultimately to humans.
3. It should be capable of been metabolized by the body and not subject to further detoxification procedure in the liver. There should not be a residue build-up in fatty tissue. Ideally, it should be water-soluble because if it is fat-soluble, it might be unavailable for antimicrobial action, since micro-organisms grow in the aqueous phase.
4. It should be stable in the food product and not react with other additives or natural components of food. It should exhibit no taste, odour or colour.
5. It should be cheap and be able to pay for itself by reducing spoilage and minimizing food borne illness.

2. **Anticaking Agents**

These are anhydrous substances that can pick up moisture without themselves becoming wet. In other words, they immobilize moisture coming in contact with a food material. They are added to particulate products, such as dry mixes, to prevent the particles from clumping together and so keeps the product free flowing. Anticaking agents are used to ensure that powders such as flour or salt remain free flowing. compounds that are used as anticaking agents include bone meal, polyphosphates, silicates, stearates, gluconates, salts of long chain fatty acids (such as myristic, palmitic and stearic).

Answers to Self-Assessment Exercises 2

1. Types of Fermentation

Alcoholic fermentation
Lactic acid Fermentation
Acetic acid Fermentation

2. The advantages of Vacuum packaging

The product is placed in a film of low oxygen permeability, air is evacuated and the package is sealed. Under conditions of a good vacuum, headspace O_2 is reduced to <1% while CO_2, produced from tissue and microbial respiration, eventually increases to 10-20% within the package headspace. These conditions, i.e. low O_2 and elevated CO_2 levels, help extend the shelf life of meat by inhibiting growth of normal aerobic meat spoilage microorganisms particularly *Pseudomonas* and *Altermonas* species.

UNIT 4 PROCESSING OF SPECIFIC FOOD COMMODITIES I: ROOTS, TUBERS, CEREALS AND LEGUMES

CONTENTS

4.1 INTRODUCTION

In a developing country like ours, the need for improved preparation, processing, preservation and storage techniques as a way of enhancing demand for indigenous, locally consumed foods, coupled with increased application of food science and technology not only to boost our dwindling agricultural production, but also to ensure that harvested seasonal foods are adequately preserved and/or kept under good storage conditions, cannot be over-emphasized. This practice has brought wealth and prosperity to many nations and has greatly contributed to the raising of the standard of living in the industrialized countries of the world.

4.2 Learning Outcomes

By the end of this unit, you will be able to discuss the examples of:

- Tubers (yam, cassava) that are processed by dehydration to make flours
- Cereals and legumes that are also dehydrated and milled to flour to produce new food
- The fermentation of maize and African locust bean to make new flavoured foods.

4.3 Processing of Root and Tuber Crops

Roots and tubers are agricultural products which grow beneath the soil. They include Yam (Dioscorea sp), Cassava (Manihot sp), Sweet potato (Ipomoea batatas) and Cocoyam but major traditional food products of importance are obtained from yam and cassava. They represent the most important source of energy in the diet of a tropical man. They have very high amounts of carbohydrates and trace amounts food groups and are often taken with other food materials that will provide fats, proteins and other essential nutrients. Sweet potato and cocoyam are often consumed without processing.

4.3.1 Yam

Yams make up the genus Dioscorea and belong to the family Dioscoreaceae. They include water yam (Dioscorea alata), the Chinese yam, or Chinese potato (*Dioscorea batatas*), the air potato (*Dioscorea bulbifera*), the elephant's foot (*Dioscorea elephantipes*), and cush, or yampi (*Dioscorea trifida*). Yams are good sources of the chemical diosgenin, a precursor of progesterone, cortisone, and other medically important steroids. Many varieties occur within these species, and the resulting yams may grow up to 2.4 m (8 ft) long and weigh up to 45 kg (100 lb) with brown or black skin and flesh that is white, purple, yellow, or red. Yams have been domesticated independently in many different parts of the world for their edible tubers. Yams are a valuable source of carbohydrates to the people of Nigeria and indeed of West Africa. The most economically important species grown in Nigeria are white yam (Dioscorea rotundata Poir.), water yam (*Dioscorea alata*), and yellow yam (*Dioscorea cayenensis*).

Yams are grown in fairly high rainfall areas with a distinct dry season of not more than five months and a rainy season of not less than five months grown mostly in middle belt and southern parts of Nigeria.

The usual method of yam propagation is to use the crowns of the large tuberous root or cuts of the large tuberous root or to plant whole small tubers. The climbing vines are supported on stakes or on a trellis. The plants are spaced 30 to 60 cm (12 to 24 in) apart in rows. The roots are harvested after they reach a suitable size and can be stored for several months at temperatures of 12 - 20 °C.

Traditionally, yams are processed into several products for immediate consumption in Nigeria. They are often eaten as boiled yam, roasted or fried yam (*Dundu*), grated and fried balls (*Ojojo*) pounded yam (*Iyan*) and yam flour (*Elubo*). Yam can only be processed into yam flour ("Elubo" in Nigeria and "Kokonte" in Ghana) for storage.

4.3.2 Yam Flour (Elubo)

Yam flour is a dehydrated milled product obtained from yam. It is a smooth brown, or white or yellow powder rich in carbohydrates. Elubo is common among the Yoruba speaking people of Nigeria but is now gradually increasing in popularity among groups where "amala" has never been a staple food. This may be due to its ease of production, its shelf stability and a convenient way of adding value to mechanically injured tubers during harvesting. These damaged tubers generally have short keeping qualities. Elubo is prepared by reconstituting in boiling water with continuous stirring until a stiff gel of the desired consistency called "Amala" is obtained. Elubo is commonly produced in large quantities in Oyo, Osun, Kwara, Benue, and Kogi States. It is an economic item whose appeal cuts across all strata of social and economic class.

Traditional Production of Elubo

Raw yams are peeled manually, sliced (optional), washed and heated over a wood fire (parboil). The fire under the vessel is removed when the water is uncomfortably hot and left for about 8 – 13 hours after which they are removed and spread outside in the sun for drying. The dried pieces are then crushed, milled and sieved to obtain the characteristic smooth brown, white or yellow powder called Elubo. Problems associated with the traditional process are:

i. Low level of hygiene.
ii. During parboiling, some of the yam pieces become overcooked and such pieces are usually discarded.
iii. Drying time depends on the prevailing weather conditions. Under the best conditions, it takes 2 – 5 days.
iv. Since they are usually spread on bare floor, chances of contamination by extraneous matter and infestation by rodents and pests is quite high.
v. The operations involved vary from one place to the other, leading to inconsistencies in the products obtained from different locations.
vi. The finished product often contains pebbles, fecal matter, dead insects and their eggs among others.

4.3.3 Ojojo

"Ojojo" is a fried food product obtained from grated water yam (Dioscorea alata) only. It is a popular food product in the southern part of Nigeria, especially among the Yorubas where it can serve as a snack or main meal with "eko".

Traditional Production of Ojojo

Water yam is peeled, cut into large pieces and manually grated yam is then mixed with chopped peppers, onions, tomatoes and salt after which it is made into small balls and fried in groundnut oil for about 5-8 minutes. It keeps for about three days and is often refried as means of preservation.

Problems associated with the traditional production process

Grating: The manual grating operation is time consuming, labour intensive, and with a high risk of injury.

Browning: Water yam undergoes browning right from when it is peeled. It undergoes further browning during and after grating especially when it is not fried immediately.

Hygiene: The traditional processors generally have a low level of hygiene. This is probably a contributory factor to the short shelf-life of the commodity.

4.3.2 Cassava

Cassava is the common name for any of several related plants native to tropical regions of America. Cassava is the West Indian name; manioc, or mandioc is the Brazilian name; and juca or yucca is used in other parts of South America. Cassava is one of the most important world food crops and it grows in a bushy form, up to 2.4 m (8 ft) tall, with greenish-yellow flowers. The roots are up to 8 cm (3 inches) thick and 91 cm (36 inches) long. Manioc or cassava is widely cultivated as an important source of starch and staple food among many tropical peoples. Many varieties and closely related species contain the poison hydrocyanic acid, which can be removed only by cooking the root. A related species, *M. dulcis*, is sometimes grown as fodder for livestock. There are two major species of cassava in Nigeria namely the sweet cassava (*Manihot palmata*) and bitter cassava (*Manihot utilissima*). The bitter variety contains a poisonous bitter juice (hydrocyanic acid) which must be extracted before it is safe for consumption. Because the bitter species predominates in Nigeria, it undergoes rigorous processing to ensure that the cyanide content is reduced to harmless levels. This volatile poison can be destroyed by heat in the process of preparation to produce wholesome foods. Human consumption of fresh unprocessed roots has been linked with a number of chronic disorders, high occurrence of endemic goitre and various neurological degenerative syndromes such as ataxic neuropathy and cretinism and occasionally, death due to the presence of toxic cyanogens.

The cyanogenic glycosides produce hydrocyanic acid (HCN) when the action of an endogenous enzyme, linamarase, is initiated by crushing or otherwise damaging the cellular structure of the plant. The cyanide in cassava exists as bound glucosides, cyanohydrins and free cyanide (HCN). The utilization of cassava roots for both human and animal nutrition appears to be limited by the presence of these cyanogenic glycosides. As a result, the roots have to be processed by a wide range of traditional methods in order to reduce their toxicity and improve palatability.

Cassava roots are processed into cassava flour, or tapioca, or they may be fermented into an alcoholic beverage. Cassava products are also used as laundry starches and fabric sizing and in the manufacture of explosives and glues. The root in powder form is used to prepare farinha, a meal used to make thin cakes sometimes called cassava bread. The starch of cassava yields a product called Brazilian arrowroot. In Florida, where sweet cassava is grown, the roots are eaten as food, fed to stock, or used in the manufacture of starch and glucose.

In Nigeria, about 70% of cassava produced is used for gari production other commonly obtained product from cassava processing are fufu and lafun.

4.3.2.1 Garri

"Garri" is fermented, gelatinous granular flour obtained from cassava. It is one of Nigeria's most popular staple foods and is presumed to contribute as much as 60% of the total calorie intake of the population. Garri is a cheap source of carbohydrate for many Nigerians and can be consumed sometimes twice a day, either it's intact form soaked with sugar or salt or further transformed into garri meal (eba) and eaten with soups or stew. Because it is a ready-to-eat and easy to prepare food item, its acceptability cuts across all economic and social strata. The popularity of garri a major staple food is at a peak among the Yoruba and Ibo tribes.

Traditional Production of Garri

Cassava is peeled, washed, grated into a watery pulp, poured into sacks, and allowed to ferment for about 1-4 days. The resulting pulp is sieved, roasted and spread out in an open area to cool. Gari is then bagged in sacks of various sizes till it is needed for commerce or consumption.

Problems associated with traditional production

Nature of Cassava: No emphasis is placed on the use of freshly harvested cassava tubers. Hence, the cassavas often used have been harvested for 2-3 days before processing starts.

Peeling and Washing: Cassava is peeled manually – a process which takes considerable time. Rather than continue processing immediately, the peeled cassava is sometimes left overnight resulting in browning of the tubers. Washing of the tubers is usually carried out with water obtained from streams. To the traditional processors, the nature, the type and source of water is not a critical factor.

Grating: The grating operation is carried out using outstretched, perforated tin. The efficiency of which is a function of the degree of perforation and applied pressure. This process apart from being crude increases the chances of accidental bruising of hand, especially the fingers.

Roasting: More often than not, the gari is not allowed to dry completely, rather it is half dried and spread in the sun thus sacrificing quality in the name of profit maximization.

Dewatering: This is done by placing heavy stones on the grated mash packaged in jute bags and sackcloths. This process is not only unhygienic, it also result in accumulation of sand particles inside the final product.

4.3.2.2 Fufu

"Fufu" is wholly carbohydrate based food material obtained from cassava. It is commonly eaten (with soup) in the core East and Southwest parts of Nigeria. It has a generally wide acceptance as reflected in the fact that it can serve either as a breakfast, lunch or dinner meal in fufu-eating areas of the country.

Traditional Production of Fufu

Raw cassava tubers are manually peeled and soaked in a big clay pot for about 3-4 days. Fermentation takes place during this period and the fermented tubers are then crushed, sieved and allowed to sediment. The sediment (wet fufu) is then packed in sacks and de-watered under heavy stones. The de-watered product is stored in sacks until it is needed.

Problems Associated with Traditional Production

The major shortcomings of the traditional process are its irritating and undesirable odour, its low shelf life as well as not observing the basic tenets of hygiene.

4.3.2.3 Lafun

"Lafun" is wholly carbohydrate-based food material obtained from cassava. It is commonly eaten in the Western part of Nigeria with soup. Its appeal, cuts across all strata of economic life.

Traditional production of Lafun

Freshly harvested cassava tuber is peeled and soaked in water either in a pot or big container. After about three days, the soaked tubers is hand-crushed after which it is spread on the floor or a platform for solar drying. The drying process takes three or more days depending on the environmental conditions. When it is sufficiently dry, it is then milled and sieved to obtain lafun. It is then stored in sacks of jute bags till it is needed.

Problems of Traditional Production Lafun

Drying Process: The sun-drying process is inefficient, time consuming and erratic especially where weather conditions fluctuate. When improperly dried, the flour cakes and is susceptible to yeast and mould attack.

Hygiene: Very little consideration is given to hygiene. This is evidence in the grooming of the processors and the dirtiness of the floor where the crushed tubers are spread.

Process Time: The process is time consuming. So much time is lost during the manual peeling process as well as during the sun-drying operation.

4.3.3 Sweet Potato

The sweet potato classified as *Ipomoea batatas*, belongs to the family Convolvulaceae. The species called wild sweet-potato vine, manroot, or man-of-the-earth is classified as *Ipomoea pandurata*. Sweet potato which is native to tropical America, is cultivated on sandy or loamy soils throughout many warm regions of the world, and exists as an important food staple in a number of countries. It is planted primarily for its thick, edible roots, called sweet potatoes. Two main types are commonly cultivated: a dry, mealy type, and a soft, light-to-deep-yellow, moist-fleshed type. The species often called wild sweet-potato vine, manroot, or man-of-the-earth is not edible, but is cultivated as an ornamental vine. The sweet potato yields an important starch, which is used commercially for sizing textiles and papers, for the manufacture of adhesives, and in laundries. The pink and yellow varieties are rich in carotene, the precursor of vitamin A.

Self- Assessment Exercises 1

1. State the Problems of Traditional Production Lafun
2. Briefly Describe Fufu

4.4 Cereal and Legumes

The common cereals in the tropics are maize, sorghum, rice, and millet. They are good sources of carbohydrates, vitamins and minerals. They can be processed into a wide range of food items and snacks. This characteristic feature makes cereals indispensable in the diet of the tropical man. Legumes refer to the group of edible plant proteins which belong to the family leguminosae. They are major type of plants that supply the body with proteins. Examples are pigeon pea (*Cajanus canjan*), lima bean (*Phaseolus lunatus*), cowpea (*Vigne unguiculata*) and groundnut (*Arachis hypogea*). They supply important minerals and vitamins essential for the normal functioning of metabolic activities.

4.4.1 Kokoro

"Kokoro" is a snack common among the Egbas of Yoruba land. It is often taken as light refreshment and can be used in entertaining guests with soft drinks. The two main types of kokoro are the white and the brown type. The brown kokoro is the most popular and most consumed form.

Traditional Processing of Kokoro

Maize is washed, dried and milled to obtain maize flour. The flour is pre-gelatinized with sugar and salt added, and the resulting dough is cooled, sprinkled with maize flour and molded into desired shapes and sizes. Then it is fried in vegetable oil, drained and cooled to obtain the ready-to-eat snack (kokoro). The product is usually covered with leaves and packaged in thin polyethylene nylons. The main method of preservation is by refrying in oil since the shelf-life is short (4 – 5 days).

Problems associated with traditional processing

Preservation technique: The method of preservation often employed (refrying) predisposes the commodity to oxidative rancidity and development of burnt flavours.

Raw materials quality: No consideration is given to the quality of maize, sugar, salt, and oil used in the processing of Kokoro.

Hygiene: The level of hygiene of the processors and that of the processing environment is generally low.

4.4.2 Ogi or Pap or Akamu

"Ogi" or "Pap" or "Akamu" is fermented product obtained from maize or guinea corn. It is an essential cereal meal of Nigerians especially the Yorubas and is the first major food given to babies from birth to weaning. It is commonly eaten with "Akara" (Bean cake) or "Moin-moin" (Bean meal) or "Bread" or "bean potage". Ogi is usually consumed in a paste form and can also be consumed in a solid cooked form called "Agidi" or "Eko". Both forms employ reconstituting wet ogi with hot water. It is entirely a carbohydrate based food and has been implicated in the incidence of kwashiorkor in children fed solely with it.

Traditional Production of Ogi

Raw maize grains are steeped in warm or cold water for 2-3 days. It is then wet-milled and sieved. The filtrate is allowed to sediment and the water decanted. The resulting product is Ogi and It is usually packed in leaves or stored under water until it is needed. The water is usually changed regularly (at least once a day) to avoid spoilage.

Problems of Traditional Processing of Ogi

The product is susceptible to microbial spoilage due to its high moisture content and low hygiene ratings. The shelf life is considerably low. Storage under water encourages post-processing fermentation which leads to sources over a period of time. It is of poor nutritional status being a wholly carbohydrate based meal.

4.4.3 Tuwo

"Tuwo" is a corn-based meal made from milled white or yellow corn. It is a wholly carbohydrate-based meal commonly eaten with bean stew ("Gbegiri"). Tuwo can also be produced from rice - a delicacy popular in the northern part of Nigeria especially among the Hausas and the Fulanis. Tuwo produced from rice is called Tuwo-shinkafa while the one produced from corn is call Tuwo-masara.

Traditional Production of "Tuwo"

For Tuwo-masara, the corn grains are removed manually and sun-dried for 2-4 weeks. When it is sufficiently dry, it is winnowed, milled and bagged till it is needed for consumption. For Tuwo-shinkafa, the milled rice is used.

Problems of Traditional Processing of Tuwo

The sun-dried grains are susceptible to attack from rodents, birds and other corn and rice eating animals. This greatly reduces the quality and quantity of the grains and the quality of the flour produced. Winnowing does not remove heavy stony particles and when milled with the grains, the flour becomes sandy, indicating low quality product. The shelf life of tuwo is considerably short and could be attributed to the high moisture content of the commodity and the oxidation of the oil content of the germ. The flour is subject to infestation by micro-organisms of public health significance like *Bacillus* spp, *Clostridium welchi, Salmonella spp*, among other microbes. The microbes could be transferred from animals to the grains during the drying process, birds, dusts and soil.

4.4.4 Donkwa

"Donkwa" also referred to as "Tanfin" among the Yorubas is a corn and groundnut based snack common among the Hausas of Nigeria. It is often used as light refreshment with or without soft drinks. The wide acceptance of the snack is attributed to its sweet taste and pleasant aroma.

Traditional Production of Donkwa

Groundnuts and corn are roasted dry and milled to obtain a fine powder (flour). Ingredients referred to among the Yoruba as "atare" "iyere" "conofuru" "eso oganwo" and dry pepper are milled and mixed with the corn-groundnut flour. Sugar and salt are added to the mixture, mixed homogeneously, and then pounded in a mortar. The mixture is then molded into desired shapes and sizes to obtain ready-to-eat donkwa.

Problems with Traditional Production of Donkwa

Emphasis is not placed on the use of good quality corn and groundnut, and the ingredients added are not obtained under sanitary conditions. Oil is released during the pounding operation and this oil is susceptible to oxidation leading to rancidity and development of off- flavours. The commodity has no packaging material but is simply displayed in glass shelves, aluminum pans and bowls which makes it susceptible to pest, rodent and microbial attack. Traditional processors give little or no regard to the tenets of hygiene and this unhygienic conditions employed can be a source of food borne infection and intoxications. Thus, the chances of cross-contamination are quite high.

4.4.5 Robo

"Robo" is a locally prepared sweet and delicious snack common among the Yorubas in Nigeria. It is prepared from "Egusi" (Melon – *Citrullis vulgaris*) and pepper (*Capsicum spp*). It comes in a wide range of shapes and figures. It is commonly eaten as a snack or as a main meal together with "Ogi" or "Gari".

Traditional Production of Robo

The dry melon is shelled manually and ground on a millstone to obtain a thick paste. Onion (Allum cepa) is ground and homogeneously mashed with the melon paste. The resulting slurry is hand squeezed, mixed with wet milled pepper and salt and then molded into desired shapes and sizes. After shaping, the resulting product is fried in previously extracted melon oil until it turns brown. It is then cooled and packaged in nylon packs.

Problems of Traditional Processing

The sun-drying process is time consuming and exposes the seed to attack from pests and rodent.

The shelling process is done manually, and this process, apart from being slow, leaves little room for proper hygiene.

Grinding on a millstone is time-consuming, and manual mixing, mashing, and molding expose the product to contamination from the processors. Packaging in thin transparent nylon packs exposes the robo to both oxidative and hydrolytic rancidity, which reduces its appeal and shelf life. Storage by re-frying in melon oil after two or three days makes the robo more susceptible to rancidity and leads to the development of burnt flavours.

4.4.6 Ekuru

"Ekuru" is the traditional name of bean meal. It is a wholly cowpea-based food item and quite rich in essential amino acids. it is usually consumed as a lunch or dinner meal with "eko". It is one of the popular forms into which beans is processed among the Yoruba's of Nigeria.

Traditional Production

Beans are soaked in water for 2-3 hours. It is then dehulled and milled using small quantities of water to obtain a slurry of the right consistency. The resulting slurry is stirred, carefully wrapped in leaves, and steamed for about 45 minutes. The resulting product – ekuru – is ready to be eaten. Traditional storage is by steaming at regular intervals, usually, every other day.

Problems associated with the traditional method of preparing Ekuru

It is time consuming. It has a short shelf-life due to interaction (chemical or otherwise) between the leaves and the food item and the activities of micro-organisms.

4.4.7 Groundnut Cake

Groundnut Cake is a wholly groundnut based snack commonly referred to as "kulikuli" among the Yorubas of Nigeria. It is either eaten alone, or more commonly with "gari". Its appeal cuts across the country. The widely acceptance of groundnut cake across the country is due largely to its sweet taste.

Traditional Production of Kulikuli

Freshly harvested groundnut is sundried, sorted, immersed in brine for few minutes, drained and sundried. The dried nuts are then roasted in a heated sand-filled slay or iron pot and stirred continuously with a wooden spoon until a golden brown colour is obtained. The roasted grains are then cooled, de-hulled, winnowed, and pounded or pulverized until it is sufficiently smooth. The resulting paste is kneaded and pressed to extract oil. Some ingredients like ground pepper and salt are added and the groundnut meal is then shaped and fried in the previously extracted groundnut oil until the golden brown colour characteristic of the ready-to-eat kulikuli is obtained. The cakes are cooled and packed in open baskets.

Problems Associated with Traditional Production

Very little attention is given to hygiene by the processors. No attempt is made to sort out unwholesome and defective grains. The method employed is grossly inefficient as chaff, dirts and other extraneous matter still remain in the commodity. The pounding process is energy, labour and time consuming. There is no standard packaging material or method for kulikuli as they are simply poured into sacks and open baskets until they are needed.

4.4.8 Iru

"Iru" is fermented African locust bean (*Parkia biglobosa*). It is one of the most important food condiments in the entire savannah region of West and Central Africa. In addition to its flavouring quality, it contributes significantly to the intake of protein, essential fatty acids and B Vitamins, particularly riboflavin. It is also known as Dawadawa in Hausa land and Ogiri – Igala in Igbo land. The popularity of the fermented beans as a major condiment necessitates a review of the traditional process with a view to enhancing its image, especially among the ever increasing urban populace who place more premiums on hygienically produced food items.

Traditional Production of Iru

Locust beans are boiled for about an hour to soften the seed for removal. The hulls are removed, washed and boiled for additional ten to twelve hours to soften the cotyledon. The cotyledons are allowed to undergo wild fermentation for about two to three days. During this period, the characteristics brown colour and ammoniated odour are developed. Iru is prepared in the solid non-mucilagenous for called woro or in the marshy mucilaginous state called pete for sale or consumption.

Self- Assessment Exercises 2

1. What are the problems associated with traditional production of Kulikuli

4.5 Summary

Food processing technology is widely applied to African foods to make convenient snacks and meals. For instance tubers are dehydrated into flours. Cereals are also treated in similar fashions to produce different products. Fermentation process is applied to African locust beans to make condiments.

Tubers like yam are boiled, dried and turned into products like pounded yam and elubo. Cassava is grated after peeling, pressed and dried to make gari and other snacks. Cereals can be fermented and dried to ogi and eko products. Legumes are also processed. For example, groundnuts are used to produce kulikuli.

4.6 References/Further Readings

Aiyeleye F.B. and Eleyinmi A.F. (1997). Improved Traditional Processing Techniques for Selected Tropical Food Commodities. FADCOL Educational Press, Akure, Ondo State, Nigeria.

4.7 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. Problems of Traditional Production Lafun

Drying Process: The sun-drying process is inefficient, time consuming and erratic especially where weather conditions fluctuate. When improperly dried, the flour cakes and is susceptible to yeast and mould attack.

Hygiene: Very little consideration is given to hygiene. This is evidence in the grooming of the processors and the dirtiness of the floor where the crushed tubers are spread.

Process Time: The process is time consuming. So much time is lost during the manual peeling process as well as during the sun-drying operation.

2. "Fufu" is wholly carbohydrate based food material obtained from cassava. It is commonly eaten (with soup) in the core East and Southwest parts of Nigeria. It has a generally wide acceptance as reflected in the fact that it can serve either as a breakfast, lunch or dinner meal in fufu-eating areas of the country.

Answers to Self-Assessment Exercises 2

1. Problems Associated with Traditional Production

Very little attention is given to hygiene by the processors. No attempt is made to sort out unwholesome and defective grains. The method employed is grossly inefficient as chaff, dirts and other extraneous matter still remain in the commodity. The pounding process is energy, labour and time consuming. There is no standard packaging material or method for kulikuli as they are simply poured into sacks and open baskets until they are needed.

2. "Robo" is a locally prepared sweet and delicious snack common among the Yorubas in Nigeria. It is prepared from "Egusi" (Melon – *Citrullis vulgaris*) and pepper (*Capsicum spp*). It comes in a wide range of shapes and figures. It is commonly eaten as a snack or as a main meal together with "Ogi" or "Gari".

UNIT 5 PROCESSING OF SPECIFIC FOOD COMMODITIES II: FRUITS, VEGETABLES, MILK, MEAT AND FISH

CONTENTS

5.1 INTRODUCTION

There is need for improved preparation, processing, preservation and storage techniques in a developing country like Nigeria as a way of enhancing demand for indigenous, locally consumed foods, coupled with increased application of food science and technology not only to boost our dwindling agricultural production, but also to ensure that the seasonal foods harvested are adequately preserved and/or kept under good storage conditions. This practice has brought wealth and prosperity to many nations and has greatly contributed to the raising of the standard of living in the industrialized countries of the world.

5.2 Learning Outcomes

By the end of this unit, the student should be able to discuss the local processing of:

- fruits and vegetables
- alcoholic and non-alcoholic beverages from cereals
- milk products from milk
- meat and fish products.

5.3 Processing of Fruits and Vegetables

5.3.1 Tomatoes

Tomatoes (*Lycopersicon esculentum*) are a circular red pigment fruit belonging to the family of plants called Solanacae. It is rich in vitamins A.B.C and minerals like Iron, Sodium, Potassium as well as small amounts of carbohydrates and proteins. Tomatoes are commonly used to prepare sauce, salad and enhance the red colour of stew. Its major defect lies in its short shelf-life due to its soft nature and high moisture content. Tomatoes are grown in all part of Nigeria but more in the Northern part.

Traditional Processing of Tomatoes

There is no traditional method of processing tomatoes. Tomatoes can be dried and stored in bags. The fresh tomatoes are stored in jute bags, baskets and leaves till they are needed for consumption or commerce.

Problems of Traditional Handling of tomatoes

Storage of tomatoes in basket leads to injury which leads to microbial proliferation, deterioration and spoilage. Storage of tomatoes in sacks build-up pressure that crushes the tomatoes at the bottom. Injuries also occur from improper handling during harvesting. The shelf life of mature ripe tomatoes is about 2-3 days. The mature unripe fruits can hardly keep for 10-12 days in the absence of any form of preservation.

5.3.2 Green Leafy Vegetables

Green leafy vegetables grow abundantly during the rainy season and become scarce and expensive during the dry season in most parts of Nigeria. The availability of these vegetables during this period makes them an important inclusion in the diet of most people.

Traditional Processing of Bitter Leaf

The leaves are removed from the stalk and washed. The leaves are rubbed between the palms in cold water. The product can be dried by spreading in an area that has been cleaned of leaves, stones, grass and dirt or they can be spread on mats. Shredding, sun-drying before rubbing between hand and addition of table salt is optional. Sun-drying is associated with the following disadvantages: the intermittent nature of solar energy throughout the day and at different times of the year, contamination of the food material by microbes, dirt, and rodents, infestation of the food by insects, and the exposure of the food to weather elements such as rain and wind which cause spoilage and losses.

Open air drying is Inefficient and will generally not lower moisture content below about 15%, which is too high for storage stability of many products. To better utilize solar radiation as a source of energy for drying foods and foodstuffs, effective system have to be developed based on specific produce needs.

5.3.3 Palm Oil

Palm oil is a deep orange, viscous liquid obtained from palm fruits which is widely cultivated in the Western and Easter part of Nigeria due to the favourable weather conditions for their survival in these areas. Palm oil is an indispensable part of the Nigerian diet as it serves as a base material for a wide range of soups, and other delicacies. It is a good source of energy and fat soluble vitamins.

Local Extraction of palm oil

The process involved vary from one locality to the other, the following operations show the major steps involved in the traditional extraction process: Fruit Bunches, Separation of Fruits from Bunch, Separation from Calyx, Boiling of the fruits, Separation of fruit from Nut, Boiling to produce the Palm oil

Palm fruits with the calyx are separated from the stalk and packed in heaps for two to three days before the fruit is separated from the calyx. The separated fruits are boiled for about four hours to soften the pericarp. The boiled fruits are then transferred into a wooden mortar or a cemented pit where it is crushed gently with pestle till a mixture of nuts and crushed pulp of even consistency is obtained. Water is then added to the mixture and thoroughly mixed. Floating oil is collected, transferred into a drum and heated continuously until the oil is sufficiently extracted. The palm oil in its ready-to-use form is stored in earthenware pots, metallic drums and plastic vessels.

Problems Associated with Local Extraction of oil

The fruit is exposed and subjected to microbe-induced lipoxidation if left for 3-4 days after harvest without processing. The lipoxidation leads to hydrolyses of the oil with production of undesirable free fatty acids. When unripe fruits are used, oil of low quality and volume is obtained while the use of over ripe fruits produces oil that deteriorates rapidly with high level of free fatty acids.

There are high chances of cross contamination as a result of low level of hygiene on the part of the processors and processing environment.

The leg crushing exercise is generally unsafe. Apart from the risk of injury on a slippery floor, chances of microbial contamination are quite high especially if the state of health and hygiene of the labourers is poor. The entire process is labour intensive and time-consuming.

The Storage system employed is grossly inefficient. Earthenware pots predispose the oil to hydrolytic oxidation which leads to development of flavours and rancidity. Metallic can rust and become particles in the oil that could lead to rancidity. Plastic vessels when used to store palm oil for a long time might impart their characteristic odour on the oil.

5.3.4 Dried Okra

Dried Okra is produced by the dehydration of fresh okra pods (*Hibiscus esculentus*). The varieties mainly grown in Nigeria include long pod, green velvet pod, long green and lady finger. Okra harvesting is done manually by snapping them off the stem when their tip are still soft and can break with a snap. Dried Okra is very popular among the Yorubas where it is called "Orunla" and most part of Igbo land where it is called "Ụkpọ". It is normally made into soup with or without palm-oil, fish, roastd chicken, and other condiments and served with "Fufu", "Lafun", "Amala" or "Eba".

Traditional Production of Dried Okra

Freshly harvested pods are sliced and spread on flat dry surface for solar drying for about 4 -6days. The dried okra is packed in that state or milled into powdery form before packaging in paper or thin nylon sachets.

Problems of Traditional Processing of Okra

The major problems associated with traditional processing include: Loss of Colour (from green colour of fresh okra to brown colour in dried form), Loss of mucilaginous property, Loss of nutrients (especially vitamin C), and the risk of microbial infection (example *Bacillus cereus* can be contacted from the soil or dust). There is increased chance of skin irritation usually induced by the spines on the skin of okra pods when large quantities are processed.

Self- Assessment Exercises 1

1. How is dried okra produced traditionally?
2. What are the Problems of Traditional Handling of tomatoes

5.4 Alcoholic and Non-Alcoholic Beverages

5.4.1 Sekete

"Sekete" is a local wine obtained by the fermentation of plantain (*Musa paradisiaka*). Plantain is very common in the southern part of Nigeria and its colour ranges from complete green (unripe) to complete yellow (ripe). Sekete is preferred for its taste and alcoholic content and commonly served for entertainment and during certain traditional ceremonies and festivities.

Traditional Production of Sekete

Mature ripe plantain is peeled, cut into small sizes and soaked for fermentation to take place. The process fermentation is often catalyzed by the addition of palm wine sediments (containing the Saccharomyces yeast). After about five days, the resulting liquor (Sekete) is filtered, filled into bottles and is ready to drink.

Problems of Traditional Processing of Sekete

The level of hygiene among the traditional processors and processing environment is generally low. The water often used for soaking is usually not of potable grade. It is obtained from streams and stagnant pools and this increases the chances of water borne infections and contaminations.

The fermentation process is wild which result in a wine with different types of alcohols – many of which are not food grade. The only food grade alcohol is ethanol.

The shelf life of the product is about two to three days. This is because the fermentation process still continues after bottling a situation which results in the depletion of the sugar base and development of an undesirable sour taste. Since there is really no effective method of storage, the over-fermented liquor is distilled to obtain Local gin ("Ogogoro")

5.4.2 Local Gin ("Ogogoro")

The local gin, fondly referred to as "ogogoro" is the most widely accepted and cherished traditional alcoholic drink, especially in the southern part of Nigeria. It is obtained by the fermentation of palm wine (a whitish sap obtained from the oil palm tree). Ogogoro is served during ceremonies and festivities. It is used as organic solvent and in the manufacture of certain drugs and chemicals in industries.

Traditional Production of Ogogoro

Freshly tapped palm wine is collected, filled into a big container covered with a piece of cloth, and allowed to undergo fermentation for about 3 to 4 days. The fermented liquor is then distilled and ogogoro is collected through delivery tubes connected to the distillation apparatus. It is then filtered and stored in vessels and bottles.

Problems Associated with Traditional Production of Ogogoro

The level of hygiene is generally low because the places where palm wine is kept for fermentation are filthy most times and this can lead to contamination of the wine. The Local producers rely wholly on the natural yeast in palm wine for fermentation and it makes the process time consuming and less profitable.

The heating of the fermented wine is done with naked flame and the smoke from the flame can contaminate the wine. Also, a reasonable amount of the wine is lost in the process because the method used in condensing the wine vapour is neither effective nor efficient.

5.4.3 Burukutu

Alcoholic "Burukutu" is produced from the fermentation of cereals like maize, sorghum, millet, guinea corn, etc. and their rich in carbohydrates make it a satisfying energy giving drink. It is a creamy dirty white coloured alcoholic (28-40%/v). Non-alcoholic "Burukutu" is produced by skipping the fermentation operation. The cereal of choice is the sorghum specie. It is used to entertain visitors and during traditional festivals. Burukutu is one of the best and popular local wines in Nigeria. It originated from the Northern part of Nigeria, from the Hausas from where it spreads to other parts of the country, especially the Southern and Western parts.

Traditional Production of Burukutu

"Burukutu" is produced in different ways, depending on the locality and the type of cereal used for the production. One of the commonest methods frequently employed in the traditional production process include: Guinea corn is washed, steeped for 24 hours and pitched into baskets to drain-off the water. It is then allowed to germinate for about 4 to 5 days after which it is washed, milled and mashed with starchy powder from cassava tubers.

The mash is then filtered with pure white cloth. For Non-alcoholic Burukutu, sugar is to the filtrate and is ready-to-drink. For alcoholic Burukutu, the filtrate is allowed to ferment (possibly with wild yeast) in a sack called "Apo-Idoho" for about 2-3 days. The fermented liquor is then boiled for about 2 hours and allowed to mature for a day and the wine is ready-to-drink.

5.4.4 Kunnu

"Kunnu" is a millet-based flavoured non-alcoholic beverage, very popular among the Hausas of Nigeria with fast increase in popularity in other parts of the country. Kunnu is taken as refreshment and for its purported sedative (laxative) effect especially when served chilled.

Traditional Production of Kunnu

The major raw materials used are millet, guinea corn, ginger, spices and chillies. These materials are washed, soaked and milled. The resulting slurry is sieved and the filtrate allowed to sediment and the water atop is decanted. About 75% of the thick residue obtained is boiled with periodic addition of calculated amounts of water. The remaining 25% is then mixed with the cooled residue and sieved to obtain the ready-to-drink Kunnu. Sugar is added to taste (optional).there is no traditional method of storing kunnu.

Problems of Traditional Production of Kunnu

The shell life of kunnu is short. It gets soured up after a period of two days – a condition attributed to uncontrolled fermentation taking place in the commodity.

The level of hygiene of the processors and processing environment is generally low. Chances of contamination and contracting food borne infection are higher. This is because kunnu is made up of 25% uncooked portion. The drink produced is often grainy. This may be attributed to improper or inadequate sieving. Sometimes, kunnu is over boiled, resulting in the development of a flat, burnt flavour. Kunnu tastes differently depending on the point of production as the quantities of ingredients vary with the different production centres.

5.4.5 Pito

"Pito" is a light-brown, sweet-sour beverage with fruity flavour obtained from malted maize and/or sorghum. It is a highly nutritious drink that has found place after meals, during ceremonies, festival and other social gatherings. It is rich in minerals and certain B-Vitamins. Pito can be two forms - the alcoholic and non-alcoholic pito. The difference lies in the incorporation of fermentation step for alcoholic pito.

Traditional Production of Pito

Maize or sorghum is steeped in water for 3-4 days, washed, milled and sieved to obtain a filtrate. The filtrate is allowed to sediment while the liquid atop is poured into a container where it undergoes fermentation for 2 – 3 days. Sugar is dehydrated, added into the fermenting liquor and boiled for several hours and then cooled. The resulting product is the alcoholic pito. For non-alcoholic pito, fermentation step is omitted. Storage is in clay pots, plastic vessels and large calabashes.

Problems of Traditional Production of Pito

The level of hygiene is generally low because the local processors (usually women) give little or no regards to personal hygiene let alone hygienic food processing practices and environment. No attempt is made to ensure that the grins used are viable and wholesome. The fermentation process is wild and uncontrolled which results in a product with off-flavour and high levels of acetic acid. Heating is by firewood which leaves no room for temperature regulation during mashing and dehydration of sugar. Wood smoke freely interferes with the food system and this could alter the taste and colour.

Self- Assessment Exercises 2

1. What is Kunnu?
2. Discuss the Problems Associated with Traditional Production of

5.5 Traditional Milk Product

5.5.1 Warankasi

"Warankasi" normally abbreviated as "wara" is a soft, white, unripened cheese origin from Northern part of Nigeria, which refer to the liquid from cold milk as "Wara" and the curd texture of the cheese as "Kashi". Wara is popular among the Hausas, Fulanis and the Yorubas of Nigeria. "Wara" is a product of lactic acid fermentation of cow's milk and contains appreciable amounts of essential amino acids, minerals and salts of sodium and potassium. It provides a good source of milk for lactose-intolerant people.

Traditional Production of Warankasi

Fresh cow milk is mixed with Sodom apple leaf extract and heated for about 15-20 minutes. The milk coagulates, the surface scum removed and heating is intensified to boiling. The loose curd pieces obtained are drained and cut into various sizes for onward transmission to the ultimate consumers. The traditional method of preservation is to hold the fresh product in its whey or water form, a procedure which keeps wara fresh for 2-3 days in the absence of refrigeration.

Problems Associated with Traditional Production of Warankasi

The traditional method has no quality control measures and the processors give little or no regard to hygiene. The implication of this is cross-contamination and microbial infestation which is capable of causing food borne infections and intoxications. The health of the cows is of paramount importance because it is a function of the quality of milk produced and little attention is given by the processors to the health of the cows. This could be due to the absence of veterinary doctors in nomadic areas as well as the high cost of veterinary drugs.

The maximum shelf life of Warankasi is about 2-3 days if stored traditionally.

5.6 Meat Products

5.6.1 Suya

"Suya" is a roasted meat product obtained from beef, pork, mutton, chicken and other desirable animals. Although it is peculiar to cattle rearing areas of the country, its acceptability has made it a national product that can be found in all nooks and crannies of the country. It is highly nutritious and prone to microbial contamination.

Traditional Production of Suya

Meat is cut into small flat pieces, rinsed and salted. The salted pieces of meat are sprinkled with pepper and groundnut oil such that its external surface is covered completely. The resulting product is sundried for about 30-60 minutes after which it is roasted with direct heat from hot coal for about 1-2 hours. The roasted meat (suya) is ready-to-eat when the meat turns brow. Suya has no local storage or packaging device but it is regularly reheated at interval to improve its appeal.

Problems of Traditional Processing of Suya

Hot flames from coal, which is in direct contact with the meat, can lead to burning and destruction of valuable nutrients of the meat. The process is time consuming as it can take some 4-6 hours to prepare, Suya is commonly displayed uncovered in environments sterile and this makes the product highly susceptible to microbial attack. Also, the smoke contains good doses of harmful gases like carbon monoxide (CO) and hydrogen sulphide(H_2S).

The level of hygiene on the part of the processors and the environment is generally low and these conditions predispose the commodity to spoilage and reduce its shelf life. The processors give no thought to the state of health of animals. In some localities, diseased or dead animals are favourites. In other areas too, the use of camel meat, which is reputed to have high amounts of mercury, is in vogue. There is no packaging or storage device. The implication of this are:

- Only small amounts of meat can be processed at a time.
- Remnants cannot stay more than 2 days before deterioration sets in.
- The production process is highly labour intensive.

5.6.2 Tinko

"Tinko" is a fibrous hard and dried meat product peculiar to cattle rearing areas of Nigeria. It is a delicacy among the Hausas and Yoruba's of the country where it is commonly used in soup preparation. It is a common form into which raw meat is processed to extend its shelf life locally. Compared to boiled meat, tinko is reputed to have a higher aroma, flavour and protein rating. Many people believe that tinko is more palatable than ordinarily boiled or fried meat.

Traditional Production of Tinko

Live animals, usually camels, donkeys and horses are slaughtered, cut into pieces, washed and parboiled until it is cooked without being soft. Salt and ashes are added and the product is dried until the meat develops a deep brown colour. The resulting product is tinko

Problems of Traditional Processing of Tinko

The product has a dirty brown colour and is usually stony, a situation which could predispose consumers to health risks like appendicitis. The use of unhealthy and dead animals is a Common practice in localities where the owner sees the illness or death of his animal as an economic loss. To mitigate his perceived losses, the sick animals or its carcass is processed into tinko. The drying method employed (sundrying) is grossly inefficient and gives very little consideration to hygiene. The storage method (packing in sacks and baskets) is equally inefficient and inadequate and this gives room for microbial proliferation as well as light and oxygen induced deterioration.

5.7 Fish Products

5.7.1 Smoked Fish

In many developing countries like ours, fish processed by traditional smoking methods are extremely popular. This popularity is due to the chemical changes that occur during the smoking process. It is the chemicals produced during the smoking process that is responsible for the characteristic flavour of smoked fish. Smoked fish has a wide appeal among the general populace. It is used in soups, sauces and other food preparations.

Traditional Production of Smoked Fish

Frozen fish is thawed, salted and smoked on wire gauze placed atop a smoke source. Where fresh fish is available, it is sometimes folded and kept in place with a broom stick and salted before smoking. The viscera matters are left intact as this is believed to make the final product bulkier. The final product has a fairly shiny gloss with considerable amount of water. Packaging is non-existent and storage is in open baskets.

Problems of Traditional Processing of smoked fish

Very little consideration is given to hygiene. The processing I environment is also filled with flies while no provision is made for washing prior to the smoking operation. Smoking is done in the open with no provisions made to protect the fish from dusts, pebbles, stones and other extraneous substances. The guts, gills and kidneys are usually not removed. The high microbial load of these intestinal organs predisposes the locally smoked fish to spoilage.

This is commonly done over open fires from dried wood. However, because it is done in the open, chances of contamination from external sources are quite high.

There is no method of storage/preservation. It is re-smoked at intervals to keep warm since the shelf life of traditionally smoked fish is very short - about 3-5 days.

5.7.2 Dried Fish

Another very popular form to which fresh fish is processed is dried fish. Species commonly used are referred to in Yoruba speaking areas as “agbodo” and “ebolo”. A large proportion of fish are locally subjected to the drying operation and it is common among the people living close to the river.

Traditional Production of Dried Fish

Raw fish is salted and exposed to direct sunlight for about 8-14 days until it is sufficiently dry. Alternatively, the salted fish is place on a wire net with red-hot charcoal beneath. This is continued till the fish is sufficiently dry. The dried fishes are then stored in baskets and jute bags till it is needed.

Problems of Traditional Processing of Dried fish

Where sun-drying is involved, the product is exposed to hazards of weather and there is virtually no form of protection against microbes, insects, pests or rodents attack. Also, sand, stones, fecal matters and other extraneous substances become ingrained in the product.

The fishes are usually not washed or washed with water of poor quality before drying and very little regards is given to the quality of the raw fish as the primary consideration is purely economic. This in turn imperils the quality of the final product. It is a very time consuming process especially where sun-drying is involved.

Self- Assessment Exercises 3

1. Discuss the Traditional Production of Tinko
2. What are the problems associated with the traditional production of smoked fish

5.8 Summary

Traditional food processing techniques are used exclusively in the production of alcoholic and non-alcoholic drinks as sekete, ogogoro, burukutu and pito. Milk products are turned into cheese by enzymes from leaves. Meat is smoked into suya and sometimes parboiled and dried into tinko, while whole fish is smoked into dried fish.

Fruits are not usually processed but marketed in basket in the fresh state. Vegetables are sold in the fresh or dried form.

Alcoholic and non-alcoholic beverages are made from cereals and palm juices. Milk is processed into cheese, meat is processed into suya and tinko while fish is popularly smoked or dried.

5.9 Glossary

Baking: Cooking in an oven with dry heat (100 – 232°C)

Barbecuing: Direct heating over glowing, smokeless wood fire.

Blanching: brief immersion of fruits, vegetables and so on in boiling water or steam.

Boiling: Cooking in high temperature usually water (100°C).

Braising: Short frying followed by stewing

Broiling: Cooking with direct rays of heat.

Cooking: a process of heating in order to alter odour, flavour, and texture, and particularly to improve the digestibility of the food components.

Elubo: a smooth brown, or white or yellow powder rich in carbohydrates.

Fermentation: a process of anaerobic or partial anaerobic oxidation during which enzymes from microorganisms or the food material break down carbohydrates or carbohydrate-like material into simpler substances.

Frying: Cooking in heated fat or oil (160-200°C)

Garri: fermented, gelatinous granular flour obtained from cassava.

Grilling: Cooking with direct rays of heat.

Ojojo: a fried food product obtained from grated water yam

Pasteurization: heat treatment involving temperatures below 100°C that kills a part but not all the microorganisms present in food.

Pito: a light-brown, sweet-sour beverage with fruity flavour obtained from malted maize and/or sorghum.
Poaching: Cooking in a minimum volume of liquid at slightly below boiling temperature. **Roasting**: Cooking in open or closed vessel with just a little fat.
Preservatives: chemical agents which serve to retard, hinder or mask undesirable changes in food.
Sautéing: Tossing food in small quantity of oil.
Simmering: Cooking in water with gentle heating.
Steaming: Cooking in steam (at 100^{o}C)
Sterilization: complete destruction of microorganisms including spores and requires heat treatment of 121°C for 15 minutes.
Stewing: Simmering in a small amount of water in a closed container.

5.10 References/Further Readings

Aiyeleye F.B. and Eleyinmi A.F. (1997). Improved Traditional Processing Techniques for Selected Tropical Food Commodities. FADCOL Educational Press, Akure, Ondo State, Nigeria.

5.11 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. Traditional Production of Dried Okra

Freshly harvested pods are sliced and spread on flat dry surface for solar drying for about 4 -6days. The dried okra is packed in that state or milled into powdery form before packaging in paper or thin nylon sachets.

2. Problems of Traditional Handling of tomatoes

Storage of tomatoes in basket leads to injury which leads to microbial proliferation, deterioration and spoilage. Storage of tomatoes in sacks build-up pressure that crushes the tomatoes at the bottom. Injuries also occur from improper handling during harvesting. The shelf life of mature ripe tomatoes is about 2-3 days. The mature unripe fruits can hardly keep for 10-12 days in the absence of any form of preservation.

Answers to Self-Assessment Exercises 2

1. “Kunnu” is a millet-based flavoured non-alcoholic beverage, very popular among the Hausas of Nigeria with fast increase in popularity in other parts of the country. Kunnu is taken as refreshment and for its purported sedative (laxative) effect especially when served chilled.

2. Problems Associated with Traditional Production of Ogogoro

The level of hygiene is generally low because the places where palm wine is kept for fermentation are filthy most times and this can lead to contamination of the wine. The Local producers rely wholly on the natural yeast in palm wine for fermentation and it makes the process time consuming and less profitable.

The heating of the fermented wine is done with naked flame and the smoke from the flame can contaminate the wine. Also, a reasonable amount of the wine is lost in the process because the method used in condensing the wine vapour is neither effective nor efficient.

Answers to Self-Assessment Exercises 3

1. Traditional Production of Tinko

Live animals, usually camels, donkeys and horses are slaughtered, cut into pieces, washed and parboiled until it is cooked without being soft. Salt and ashes are added and the product is dried until the meat develops a deep brown colour. The resulting product is tinko

2. Problems of Traditional Processing of smoked fish

Very little consideration is given to hygiene. The processing I environment is also filled with flies while no provision is made for washing prior to the smoking operation. Smoking is done in the open with no provisions made to protect the fish from dusts, pebbles, stones and other extraneous substances. The guts, gills and kidneys are usually not removed. The high microbial load of these intestinal organs predisposes the locally smoked fish to spoilage.

This is commonly done over open fires from dried wood. However, because it is done in the open, chances of contamination from external sources are quite high.

There is no method of storage/preservation. It is re-smoked at intervals to keep warm since the shelf life of traditionally smoked fish is very short - about 3-5 days.

UNIT 1 PRINCIPLES OF FOOD PRESERVATION

CONTENTS

1.1 Introduction

Food preservation is the process of handling and treating a food in order to control its spoilage. It is usually achieved by stopping the attack and growth of microbes and avoiding oxidation of fats (rancidity). Preservation helps maintain the nutritional value, texture and flavor of the food.

All food preservation methods are based on the general principle of preventing or retarding the causes of spoilage caused by microbial decomposition, enzymatic and non-enzymatic reactions, chemical or oxidative reactions and damage from mechanical causes, insects and rodents. Food preservation is based on the following three principles:

1. Prevention or delay of microbial decomposition brought out by keeping out microorganisms or asepsis, removal of microorganisms through washing, filtration etc. Hindering the growth and activity of microorganisms by controlling the conditions required for the growth and activity of microorganisms using low or high temperature, drying, and maintenance of anaerobic conditions or chemicals. Killing of microorganisms by heat or irradiation.
2. Prevention or delay of self-decomposition of foods by destroying or inactivating food enzymes using the following methods: blanching, low temperature storage, chemical preservation, drying etc. Preventing or delay of chemical reactions (example, prevention of oxidation with the use of antioxidants as oxygen speeds up food decomposition and=--ntioxidants deprives food from oxygen).
3. Prevention of damage because of external factors such as insects, rodents, dust, odour, fumes, and mechanical, fire, heat or water

damage. Example use of boxes, cartons, and shock absorbing materials, sealed tight and vacuum-packaging.

1.2 Learning Outcomes

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

- Discuss food preservation
- Analyse the length of preservation of different products
- Write the reasons for preservation
- Demonstrate the food processing methods.

1.3 Food Preservation

1.3.1 Reasons for Preservation

The main reasons for food preservation are to overcome inappropriate planning in agriculture, produce value-added products, and provide variation in diet. The agricultural industry produces raw food materials for different sectors. The inadequate management or improper planning in agricultural production can be overcome by avoiding inappropriate areas, times, and amounts of raw food materials as well as by increasing storage life using simple methods of preservation. Value-added food products can give better quality foods in terms of improved nutritional, functional, convenience, and sensory properties. Consumers demand for healthier foods also affects its preservation. In developing countries variation in the diet is important to reduce over reliance on a specific type food. The important points to be considered in food preservation are:

- desired level of quality
- Length of preservation
- Target group of the products to be preserved

Food quality is defined as the degree of fitness for use or the condition indicated by the satisfaction level of consumers. When food has deteriorated to such an extent that it is considered unsuitable for consumption, it is said to have reached the end of its shelf life. It is important to measure the rate of change of a given quality attribute in studying the shelf life of foods. Safety is the first attribute, followed by other quality though the product quality attributes such as appearance, sensory, or microbial characteristics can be quite varied. Loss of quality is highly dependent on types of food, composition, formulation (for manufactured foods), packaging, and storage conditions. Quality loss can be minimized at any stage of food harvesting, processing, distribution, and storage. The consequences of failed preservation range from minor deterioration such as colour loss to food becoming extremely hazardous.

1.3.2 Length of preservation

Length of preservation is defined by the manufacturer according to criteria when the product is saleable. Best before date is set shorter than the shelf life with a good margin. Hence, the product stored at the recommended conditions is usually safe and palatable to consume a long time after the expiring date. Most products are marketed with the production date "pack date" and "best-before date" or "use-by date" or "expiration date", which may be close to the shelf life. It is important to measure the rate of change of a given quality attribute while studying the shelf life of foods. The quality of a product quality can be established using factors like appearance, yield, eating characteristics, and microbial characteristics, but ultimately the final use must provide a pleasurable experience for the consumer.

In most products, prolonged storage or shelf life is not needed, which simplifies both the transport and marketing of the foodstuff. For example, prepared dinner meals need a shelf life of about 24 hours or less. Hence, there is no point ensuring preservation of the product for weeks or months. However, foods for space travelers and food storage during wars require a very long shelf life up to 3–5 years.

1.3.3 Target group of the preserved food

It is important to know for whom the preserved food is being produced as nutritional requirements and food restrictions differs from one population group to another. Although Food poisoning is usually mild in some cases, it can be fatal, especially in infants, pregnant women, the elderly, and in immune-depressed individuals.

Self- Assessment Exercises 1

1. What are the important points to be considered in food preservation
2. How can the quality of a prouct be established?

1.4 Methods of preservation

1.4.1 Temperature based methods

Asepsis

When raw food is removed from the field or protective skin or peel, it begins to deteriorate after a short period of time. Asepsis is a process of keeping microorganisms out of food. An aseptic environment can be created by proper packaging of the food product, which separates the internal environment from the surroundings. Maintenance of good hygiene while processing the food can help in preventing the entry of microorganisms into the product.

Removal of microorganisms

Microorganisms are ubiquitous (seen everywhere) in nature, hence, the dust and dirt adhering to the raw material contain microorganisms which can be reduced by applying various pre-treatment/cooking methods.

The following methods/treatment that can reduce microbial load include:

i. Washing

ii. Trimming ingredients
iii. Discarding dirt
iv. Filtering
v. Centrifugation
vi. Sedimentation

Maintenance of anaerobic conditions/ packaging

The packaging of foods in a vacuum environment such as air-tight bags or bottles results in anaerobic environment. As most bacteria need oxygen for survival, the vacuum environment in the package slows down the bacterial spoilage of such foods.

Drying

Drying is the removal of water from food and is one of the oldest and simplest methods of preserving food. Dried foods are preserved longer because the available moisture level is so low that the microorganisms cannot grow and the enzyme activity is also controlled.

Types of drying include:

i. Sun drying
ii. Mechanical/ artificial drying
iii. Freeze drying

Dried foods are compact, lightweight, do not require refrigeration, and last much longer than the fresh foods. It should be stored in airtight containers to prevent rehydrating from moisture which promote microbial growth.

Sun drying

Sun drying uses the heat from sun rays but it is a slow process with high risk of contamination and spoilage from microbes and hazardous substances. The problem with sun drying is irregular climatic condition.

Mechanical/artificial drying

Dehydration is the use of controlled conditions of heating with forced circulation of air or artificial drier/mechanical drier compared to sun drying. With mechanical driers, fruits, fruit leathers, banana chips, tea, coffee, milk, soups, fish, meat, eggs, and vegetables can be dried year-round.

Freeze drying

Freeze-drying is a form of dehydration in which the product is first frozen and then water is removed under vacuum as vapour by sublimation. The principle behind freeze drying is that under certain conditions of low vapour pressure, water in the form of ice evaporates as water vapour directly without turning into liquid phase. The advantage is that the food structure and nutritional properties are better conserved. The disadvantage is that the equipment and its maintenance are costly.

Smoking

During smoking, foods are exposed to smoke by burning some special kinds of wood, which has two main purposes, adding desired flavouring and preserving. Smoke contains chemicals like formaldehyde, which is bactericidal and food dehydration due to smoking is responsible for its preservative action. The smoke is obtained by burning wood like oak, maple, walnut and mahogany under low breeze or wind. Most meat is smoked after curing to aid their preservation. Examples of foods preserved by smoking are smoked beef, ham, bacon, fish and meat.

Food concentration

Some liquid foods are preserved by concentration involving preservative action of reduction in water activity and development of osmotic pressure which retard microbial growth and enzymatic reactions.

Reasons for the concentration of foods are:

i. reduction in volume and weight
ii. reduction in packaging, storage and transport costs
iii. better microbial stability
iv. Convenience.
v. Tomato paste, fruit juice concentrate, soup and condensed milk are examples of food preserved by concentration. The rate of heating should be controlled to prevent localized burning of the product, particularly when it has become thickened towards the end of boiling.

1.4.2 Chemical based methods

Sugaring

A strong sugar solution (≥68%) draws water from the microbial cells thereby inhibiting the growth of microbes. Examples of foods preserved by sugaring are fruits in heavy sugar syrup, jams, jellies, marmalades, candies and sweetened condensed milk.

Pickling

Microorganisms do not grow well in acidic solutions and this is the basis of preserving fruits and vegetables by pickling. Pickling uses a mixture of salt and acid such as acetic acid (vinegar). Examples of fruits and vegetables generally preserved by pickling are raw mangoes, limes, Indian gooseberry, ginger, turmeric and green chillies.

Salting or curing

Salting is an ancient preservation method of preserving meat and fish. Curing preserves the food by drawing moisture from the meat through osmosis and makes the water unavailable for microbial growth and enzyme action. Meat is generally cured with salt or sugar, or a combination of the two. Nitrates and nitrites are also used for curing of meat, which contribute the characteristic pink colour of the meat, as well as inhibition of *Clostridium botulinum*. Salting is used for the preservation of tamarind, raw mango, Indian gooseberry, fish and meat.

Use of organic acids

Organic acids are used in food preservation because the acid condition inhibits the growth of many spoilage microorganisms. Bacteria are generally pH sensitive and low pH of organic acids penetrates the bacteria cell wall and disrupt its normal physiology and thus preserve the food. Organic acids widely used for food preservation include acetic acid, lactic acid, citric acid, and malic acid.

Self- Assessment Exercises 2

1. State the treatment employed by food scientist to reduce microbial load of foods
2. List the types of drying employed in food preservation

1.5 Summary

Food preservation techniques are used in the preservation of fruits, vegetable, meats, grains etc. Preservation can be achieved by several methods including salting, sugaring, pickling, smoking, and different types of drying. Chemicals and organic acids can also be used for food preservation

Food such as fruits, vegetable, meats, grains etc. is preserved to extend its shelf life. All food preservation techniques involves the reduction in the moisture content of the food, this reduces the growth of microbes and enzymatic activities. Heat, Salts and organic salts are used in food preservation.

1.6 References/Further Readings

Aiyeleye F.B. and Eleyinmi A.F. (1997). Improved Traditional Processing Techniques for Selected Tropical Food Commodities. FADCOL Educational Press, Akure, Ondo State, Nigeria.

1.7 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. The important points to be considered in food preservation are:
● desired level of quality
● Length of preservation
● Target group of the products to be preserved
2. The quality of a product quality can be established using factors like appearance, yield, eating characteristics, and microbial characteristics, but ultimately the final use must provide a pleasurable experience for the consumer.

Answers to Self-Assessment Exercises 2

1. The following methods/treatment that can reduce microbial load include:

vii. Washing
viii. Trimming ingredients
ix. Discarding dirt

x. Filtering
xi. Centrifugation
xii. Sedimentation
2. Types of drying employed in food preservation include:
iv. Sun drying
v. Mechanical/ artificial drying
vi. Freeze drying

UNIT 2 FOOD PRESERVATION PROCESS I: TEMPERATURE BASED PRESERVATION

CONTENTS

2.1 INTRODUCTION

Heating was used centuries ago before its action was understood and it is used to inactivate microorganisms or enzymes of food spoilage significance. Microorganisms are killed by heat because heat coagulates the food proteins and inactivates the microbial enzymes which results in death of microorganisms. Heating can be achieved using all forms of cooked food, pasteurization, sterilization by ultra-high temperature, canning etc. Pasteurization of milk is one of the most important modern applications of heat preservation.

Food preservation is accomplished by controlling or destroying the agents of food spoilage. Agents of food spoilage are present in abundance within the food and in the environments where foods are grown, harvested, processed, stored and consumed. Foods can be preserved by freezing, drying, heating, pasteurizing, sterilizing, canning, blanching and cooking.

Use of low temperature is the easiest, most convenient and least time consuming method of preserving foods. Refrigeration/freezing do not sterilize foods or destroy the microorganisms that cause spoilage but slows down the growth of microorganisms and the chemical and enzymatic changes that affect quality or cause spoilage.

Microorganisms are more likely to survive cold temperatures than hot temperatures, hence, the less effective nature of low temperature compared to thermal techniques of food preservation. The major problem with the use of freezing as a method of food preservation is that microorganisms are only deactivated and not killed and may again become active while thawing. Also, enzyme action is slowed but not stopped during freezing and these enzymes are responsible for colour and flavour changes and loss of nutrients during food preservation/storage at low temperature.

The metabolism of a living tissue is a function of the environmental temperature. Low temperature is applied to impede growth and chemical and enzymatic reactions of microbes in food. Freezing and refrigeration are among the oldest methods of food preservation.
For every 10°C temperature change, the rate of reaction changes by a factor of 2 to 3. The growth of pathogens is halted below -4°C and food spoilage microorganisms don’t grow below -10°C.

2.2 Learning Outcomes

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

- Discuss food preservation
- Write the different freezing methods used in preservation of foods
- Analyse the different between pasteurization and sterilization

2.3 Food Preservation

Human endeavour to ensure adequate supply of wholesome foods continues to today as it has been throughout the centuries. Despite the endeavours, millions of people regularly lack sufficient food for good health while others suffer the consequences of food contamination by microorganisms. Effective methods of food preservation have been man’s subject of research since civilization. The continuing crises in our world’s food supply suggest that spoilage be reduced as much as possible. Globally, the greatest nutritional deficit is found among those with problems of inadequate food production, distribution and preservation in their area.

The producer is able to keep his product on the longer shelf life, thus minimizing economic losses. The consumer can keep the product on their shelf longer, minimizing economic and convenience losses. Society benefits by wasting less food, and in some cases, minimizing public health hazards like botulism.

The shelf life of many perishable foods such as meat, eggs, fish, poultry, fruits, vegetable and baked products is limited in the presence of atmospheric oxygen, growth of aerobic spoilage microorganisms and attack by insect pests. Each of these factors, alone or in conjunction with one another, result in changes in colour, flavour, odour and overall deterioration in food quality.

Micro-organisms, such as bacteria and fungi, rapidly spoil food and enzymes, which are present in all raw foods, are catalytic substances that promote degradation and chemical changes affecting foods especially texture and flavour. Atmospheric oxygen may react with food constituents, causing rancidity or colour changes. Most preservation processes are therefore aimed at destroying or inhibiting bacteria, moulds, and yeasts.

There are six major methods commonly employed in food preservation.

1. **Temperature**
   Low temperature – Freezing, Cooling, and Chilling
   High temperature – Pasteurization, Canning, Cooking, and Tyndallisation
2. **Irradiation** – Radiolysis
3. **Moisture Reduction** – Drying, dehydration, and Concentration
4. **Fermentation** – Alcoholics, Acetic acid and Lactic acid.

These preservation operations are designed to achieve the following goals, namely:

1. To change the form or characteristics of the product and make it more attractive to consumers and easier to market.
2. Reduction of microbial load of the raw food materials.
3. Prevention of contamination from the processing operations and environment.
4. To pack, store and distribute the processed food in such a manner as to minimize post-processing contamination.

2.3.1 Low Temperature Preservation

Storage at low temperatures prolongs the shelf life of many foods as it reduces the growth rates of microorganisms and slows down many of the physical and chemical reactions that occur in foods. Low temperature preservation is based on the application of Van't Hoff equation, which shows that a decrease of about 10^{o}C in temperature of a food item halves the rate of the reactions going on in the food item. Low temperatures do not sterilize foods because the process does not kill all types of bacteria; those that survive become active in thawing food and often grow more rapidly than before freezing. Enzymes in the frozen state remain active, although at a reduced rate. Vegetables are blanched or heated in preparation for freezing to ensure enzyme inactivity and to avoid degradation of flavour. Different methods are used for freezing of meats depending on the type of meat and the cut. Pork is frozen soon after butchering, but beef is hung in a cooler for several days first to tenderize the meat.

The three methods of low temperature storage are:

i. **Cooling:** This involves the removal of a small amount of heat from a food item. It is a slight reduction in temperature of the food.
ii. **Chilling:** This involves a more pronounced reduction in temperature of the food item but it remains above freezing temperature.
iii. **Freezing:** This is a sharp reduction in temperature of a food item such that the food will undergo change of state if in liquid form (liquid will change to a solid state). This condition helps to retard microbial growth by the cold temperature and by the lack of water, which is unavailable to them when it freezes. Freezing process can be slow or fast.

Slow Freezing

Slow freezing is a condition in which ice formation is largely extra fibular in meat and extra cellular in plant tissues. Foods frozen by this method are characterized by large crystals. However, this is not often used because it is not economical and can cause physical rupture and separation of cells.

Slow freezing also known as sharp freezing occurs when food is directly placed in freezing rooms called sharp freezers. This method involves freezing by circulation of air by convection. The relatively still air is a poor conductor of heat and that is the reason for long time required to freeze the food. The temperature ranges from -15 to -29°C and freezing may take 3 to 72 hours. The ice crystals formed are large and found in between cells (i.e. extracellular spaces because of which the structure of food is disrupted). The structure of food is not maintained and thawed food cannot regain its original water content. Large ice crystals create quality problems like mushiness in vegetables.

Fast Freezing

This is a condition in which ice formation is largely intra-fibular in meat and intracellular in plant tissues. Foods frozen by this method are characterized by small crystals.

Quick freezing

Vigorous circulation of cold air enables freezing to proceed at a moderately rapid rate. The temperature is kept between -32°C to -40°C and the food attains the stage of maximum ice crystal formation in 30 minutes or less. Small ice crystals are formed within the cells and therefore, it does not damage the structure of food. The structure of original food is maintained on thawing.

Difference between slow and fast freezing

Fast freezing	Slow freezing
1. Rates of cooling of less than 1°C/min. Ice crystals form in extra-cellular locations 2. Large ice crystals formation 3. Maximum dislocation of water 4. Shrinkage (shrunk appearance of cells in frozen state) 5. Less than maximum attainable food Quality	1. Produces both extra-cellular and intracellular (mostly) locations of ice crystals 2. Small but numerous ice crystals 3. Minimum dislocation of ice crystals 4. Frozen appearance similar to the unfrozen state 5. Food quality usually superior to that attained by slow freezing

Freezing Systems Based on Mode of Operation

Batch freezing

Batch freezing is mostly used for small operations if a variety of foods are to be frozen. A batch freezer may be selected over continuous freezing because it is more versatile. It is also likely to be used for products with longer freezing times since with a batch freezer there is better utilization of floor space due to the multi-layer arrangement of loading. It is difficult to choose on an exact line of demarcation, but generally freezing times longer than one hour would usually require a batch mode of operation.

Continuous freezing

Continuous freezing is used in large scale production lines since it is best method for freezing individual portions, such as small pieces of vegetables. The major advantage of using a continuous freezer for smaller and/or thinner products is that since they freeze quickly, they will also thaw quickly and the delays that occur with a batch freezing operation may be overcome easily. It allows quick handling after freezing and a quick transfer to the cold store.

Batch/ continuous freezing

These kinds of freezers are usually batch type freezers operated with trolleys which are loaded in sequence at fixed-time intervals rather than all at one time as in the truly batch freezer.

Quality loss Due to freezing Temperatures

Freezing is done to preserve food by reducing the product temperature, thereby slowing the quality deterioration processes. Yet, some Chemical and physical changes like oxidation of fat, growth of microorganisms, enzymatic reactions and loss of surface moisture (dehydration) take place on long storage of frozen foods. Other observed changes include:

- Flavour changes of food
- Textural changes
- Colour changes
- Moisture loss
- Freezer burn
- Nutritional value of frozen foods

2.3.1.1 Refrigeration

Refrigeration is the process of lowering the temperature in a given space and maintaining it for the purpose of chilling foods, preserving certain substances, or providing an atmosphere conducive to bodily comfort. Cold storage is the storing of perishable foods or other items under refrigeration. Refrigeration retards bacterial growth and adverse chemical reactions that occur in the normal atmosphere.

The life of many foods may be increased by storage at temperatures below 4°C (40°F). Fresh fruits, vegetables, eggs, dairy products and meats are commonly refrigerated foods. Some tropical fruits like bananas are damaged if exposed to low temperatures.
In mechanical refrigeration, constant cooling is achieved by the circulation of a refrigerant in a closed system, in which it evaporates to a gas and then condenses back to a liquid again in a continuous cycle. If no leakage occurs, the refrigerant lasts indefinitely throughout the entire life of the system. Refrigeration requires a constant supply of energy or power and a method of dissipating waste heat to maintain cooling. The two main types of mechanical refrigeration system are:

i. The compression system used in domestic units for large cold storage applications and for most air conditioning.

ii. The absorption system employed largely for heat-operated air conditioning.

Refrigeration/ chilling temperature (0 to 5°C)

Refrigeration is generally practiced both at home and industry. In chilling, the temperature of a food is reduced generally to between -1°C and 7°C and thus subsequent storage at refrigerated temperature extends the shelf life of both the fresh and processed foods. It is not the sole method for preserving foods; therefore, it is used as an adjunct process to extend the storage life of mildly processed (pasteurized, fermented and irradiated foods) and low-acid foods.

Chilling and refrigerated storage retards the growth of bacteria, particularly the thermophiles and mesophiles but psychrophillic spoilage bacteria such as *Listeria monocytogenes*, *Yersinia enterocolitica* etc., however, can spoil food during low temperatures storage.

Temperatures of 5 to 6°C or less retard the growth of most food poisoning microorganisms except *Clostridium botulinum* type E. Foods kept at this temperature slow down the microbial activities and chemical changes that result in spoilage. Mechanical refrigerator or cold storage is used for this purpose. Meats, poultry, eggs, fish, fresh milk and milk products, fruits, vegetables, etc. can be preserved for 2-7 days by refrigeration.

1.3.1.2Freezing (-18 to -40°C)

Freezing storage provide an excellent means of preserving the nutritional quality of foods. At sub-freezing temperatures, the nutrient loss is extremely slow for a typical storage period used in commercial trade.

Freezing is the removal of heat from the packaged or whole foods resulting in the temperatures between slightly below the freezing point of food to -18°C. Frozen foods last many months without spoiling, however, some quality loss may occur. Some microorganisms grow even at sub-freezing temperatures as long as water is available. Conversion of water to ice increases the concentration of dissolved solutes in unfrozen water and leads to low water activity. The concerted effect of low temperatures, reduced water activity, and pre-treatment of blanching prior to freezing of products yield longer shelf life.

No single freezing system can satisfy all freezing needs, because of the wide variety of food products and process characteristics. The selection criteria of a freezing system depend on the type of the product, reliable and economic operation, easy cleanability, hygienic design and desired product quality.

Although all commercial freezing processes are operated at atmospheric conditions, there are potential applications of high-pressure assisted freezing and thawing of foods. The pressure induced freezing point and melting point depression enables the sample to be super cooled to low temperature (-22°C at 207.5 M pa) resulting in rapid and uniform nucleation and growth of ice crystals on release of pressure.

During freezing, water in food turns into ice and makes the water unavailable for reactions to occur and for microorganisms to grow. Most perishable foods like poultry, meats, fish, ice-creams, peas, vegetables, and juice concentrates can be preserved for several months at this temperature. Enzyme action may still produce undesirable effects on flavour and texture during freezing of vegetables.

The Freezing Process

The freezing of food involves lowering its temperature below 0°C, resulting in the gradual conversion of water present in the food into ice. Freezing is a crystallization process that begins with a nucleus or a seed derived from either a non-aqueous particle or a cluster of water molecules (formed when the temperature is reduced below 0°C). This seed must be of a certain size to provide an adequate site for the crystal to begin to grow. If physical conditions are conducive to the presence of numerous seeds for crystallization, then a large number of small ice crystals will form but if only a few seeds are initially available, then a few ice crystals will form and each will grow to a large size. The size and the number of ice crystals influence the final quality of many frozen foods; for example, the smooth texture of ice cream indicates the presence of a large number of small ice crystals.

The freezing process of pure water is initiated by lowering the temperature to slightly below 0° C called super-cooling. As ice crystals begin to grow, the temperature returns to the freezing point. During the conversion of liquid water to ice, the temperature of the system does not change. The heat removed during this step is called the latent heat of fusion (equivalent to 333 joules per gram of water). Once all the water is converted to ice, any additional removal of heat will result in a decrease in the temperature below 0°C.

The freezing of foods exhibits a number of important differences from the freezing of pure water. Foods do not freeze at 0°C instead; most foods begin to freeze at a temperature between 0° and -5°C (32° and 23°F) owing to the presence of different soluble particulates (solutes) in the water present in foods. Also, the removal of latent heat in foods during freezing does not occur at a fixed temperature. As the water present in the food freezes into ice, the remaining water becomes more concentrated with solutes. Foods have a zone of maximum ice crystal formation that typically extends from -1° to -4°C (30° to 25°F). Damage to food quality during freezing can be minimized if the temperature of the product is brought below this temperature range as quickly as possible.

Industrial Freezers

The rate at which heat is removed from a food during freezing depends on how fast heat can travel within the food and how efficiently it can be liberated from the surface of the food into the surrounding atmosphere. Industrial freezers remove heat from the surface of a food as rapidly as possible. There are several types of industrial freezers, including air-blast tunnel freezers, belt freezers, fluidized-bed freezers, plate freezers, and cryogenic freezers.

i. **Air-blast tunnel freezers and belt freezers:** precooled air at approximately -40°C is blown over the food products. Packaged foods such as fruits, vegetables, bakery goods, poultry, meats and prepared meals, are usually frozen in air-blast tunnels. The packages are placed on hand trucks and then rolled into the freezer tunnels.
ii. **Belt freezers:** precooled air at approximately -40°C is blown over the food products. In a belt freezer, food is placed on a conveyor belt that moves through a freezing zone. Bakery goods, chicken parts and small flat pieces of meats are frozen using a belt freezer.
iii. Fluidized-bed freezers are used to freeze particulate foods such as peas, cut corn, diced carrots and strawberries. The foods are placed on a mesh conveyor belt and moved through a freezing zone in which cold air is directed upward through the mesh belt and the food particulates begin to tumble and float. The tumbling exposes all sides of the food to the cold air and minimizes the resistance to heat transfer at the surface of the food.
iv. Plate freezers are used to freeze flat products, such as pastries, fish fillets, beef patties, as well as irregular-shaped vegetables that are packaged in brick-shaped containers, such as asparagus, cauliflower, spinach and broccoli. The food is firmly pressed between metal plates that are cooled to subfreezing temperatures by internally circulating refrigerants.
v. Cryogenic freezing is used to freeze food at an extremely fast rate. The food is moved through a spray of liquid nitrogen or directly immersed in liquid nitrogen. The liquid nitrogen boils around the food at a temperature of -196°C (-321°F) and extracts a large amount of heat.

2.3.1.3 Quality of Frozen Foods

Frozen foods have the advantage of resembling the fresh product more closely than the same food preserved by other techniques. However, improper freezing or storage of foods may result in detrimental quality changes. When foods with high amounts of water such as fish are frozen slowly, they may experience a loss of fluid (drip) upon thawing. This fluid loss causes dehydration and nutrient loss in frozen food products.

During frozen storage, the ice crystals present in foods may enlarge in size, producing undesirable changes in texture. Freezing causes the water in food to expand and tends to disrupt the cell structure by forming ice crystals. In quick-freezing, the ice crystals are smaller, producing less cell damage than in the slowly frozen product. This phenomenon is commonly observed when the storage temperature is allowed to fluctuate. Some liquid foods that are frozen slowly, such as egg yolk, may become coagulated. Quick-frozen foods retain their nutrients almost intact, and their characteristic flavour remains virtually undiminished. Frozen foods must be stored and kept at 0°C (32°F) or below, because even partial thawing and refreezing lowers the overall quality of the product.

Improperly packaged frozen foods lose small amounts of moisture during storage, resulting in surface dehydration (called freezer burn). Frozen meats with freezer burn have the appearance of brown paper and quickly become rancid. Freezer burn can be minimized by the use of tightly wrapped packs and the elimination of fluctuating temperatures during storage. Because of the high cost of refrigeration and power, frozen foods are comparatively expensive to produce and distribute.

2.3.1.4 Advantages of Cold Temperature preservation of Foods

i. The storability of the food is extended.
ii. In the production of carbonated beverages, $C0_2$ becomes more soluble in water.
iii. The organoleptic characteristics of wine are improved.
iv. The slicing response of bread is improved
v. Post-harvest metabolic activities of plant tissues and post slaughter metabolism of animal tissues are reduced.
vi. It helps in precipitating waxes from edible oils.
vii. It also controls the rate of growth and metabolism of desirable food microorganisms.

2.3.1.5 Some Terms used in Cold Storage of Foods

i. **Super cooling:** Cooling below the freezing point of a food item.
ii. **Eutectic mixture**: A solution from which water cannot be crystallized.
iii. **Freeze drying:** A process by which frozen food is placed in vacuum thereby causing rapid loss of water by sublimation.
iv. **Lypholisation**: Freeze drying
v. **Freezer burn**: The drying of the surface of poorly wrapped foods such as bread due to sublimation of water.
vi. **Cook freeze**: Cooking, chilling and immediately freezing foods.

vii. **Regeneration**: A process in which food is returned to its original state for eating after chilling.
viii. **Chilling injury**: The result of freezing a food product under a wrong storage temperature because every food items has a specific temperature range of preservation.

2.3.1.6 Refrigeration and Freezing Compared

Although refrigeration and freezing bring down the temperature of food, the two processes differ remarkably. The following is a brief outline of their differences:
In refrigeration, the food is stored at a temperature of $4^{o}C$ ($40^{o}F$) or below whereas in freezing, food is stored at $-18^{o}C$ ($0^{o}F$).
There is no single method of food preservation technique that provides protection against all hazards for an unlimited period of time.

Self- Assessment Exercises 1

1. What is the Advantages of Cold Temperature preservation of Foods?
2. State the two main types of mechanical refrigeration system

2.4 Summary

Foods can be preserved by freezing, drying, heating, pasteurizing, sterilizing, canning, blanching and cooking. Use of low temperature is the easiest, most convenient and least time consuming method of preserving foods. Refrigeration/freezing do not sterilize foods or destroy the microorganisms that cause spoilage but slows down the growth of microorganisms and the chemical and enzymatic changes that affect quality or cause spoilage.

Foods can be preserved by freezing, drying, heating, pasteurizing, sterilizing, canning, blanching and cooking.
Use of low temperature is the easiest, most convenient and least time consuming method of preserving foods.
Refrigeration/freezing do not sterilize foods or destroy the microorganisms that cause spoilage but slows down the growth of microorganisms and the chemical and enzymatic changes that affect quality or cause spoilage.

2.5 References

Swaroop, K.R. and Giddaiah, R (2020). Societal Changes and Its Impact On Food Habits. *International Journal Of Scientific & Technology Research,9(2):246-271*.

UNHCR (1997) Commodity Distribution; a Practical Guide for Field Staff, 77 pages.

Kumar, A (2019). Food Preservation: Traditional and Modern Techniques. *Acta Scientific Nutritional Health*, 3(12): 45 – 49

Lianou, A., *et al*., (2016). "Microbiological spoilage of beverages". In The Stability and Shelf Life of Food. (Subramanian, P. ed.) Second Edition Woodhead Publishing, India, 3-42.

2.6 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. Advantages of Cold Temperature preservation of Foods

i. The storability of the food is extended.

ii. In the production of carbonated beverages, $C0_2$ becomes more soluble in water.

iii. The organoleptic characteristics of wine are improved.

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v. Post-harvest metabolic activities of plant tissues and post slaughter metabolism of animal tissues are reduced.

vi. It helps in precipitating waxes from edible oils.

vii. It also controls the rate of growth and metabolism of desirable food microorganisms.

2. The two main types of mechanical refrigeration system are:

iii. The compression system used in domestic units for large cold storage applications and for most air conditioning.

iv. The absorption system employed largely for heat-operated air conditioning.

UNIT 3 FOOD PRESERVATION PROCESS II: USE OF IRRADIATION AND MOISTURE REDUCTION

CONTENTS

3.1 INTRODUCTION

Food irradiation involves the use of either high-speed electron beams or high-energy radiation with wavelengths smaller than 200 nanometres, or 2000 angstroms (e.g. X rays, gamma rays and corpuscular radiations). These rays contain sufficient energy to break chemical bonds and ionize molecules that lie in their path. The two most common sources of high-energy radiation used in the food industry are cobalt-60 (60Co) and Caesium-137 (137Cs). At same level of energy, gamma rays have a greater penetrating power into foods than high-speed electrons.

Treatment of food with ionizing radiation is a useful tool for control of the presence of food borne non-spore-forming pathogenic bacteria and other microorganisms such as *Campylobacter*, *Escherichia coli* 0157:H7, *Listeria monocytogenes*, *Salmonella*, *Staphylococcus aureus* and parasitic organisms such as *Trichina*. These organisms cause diarrhea and in some cases, death.

The unit of absorbed dose of radiation by a material is denoted as the gray (Gy), one gray being equal to the absorption of one joule of energy by one kilogram of food. The energy possessed by an electron is called an electron volt (eV). One eV is the amount of kinetic energy gained by an electron as it accelerates through an electric potential difference of one volt. It is usually more convenient to use a larger unit such as mega electron volt (MeV), which is equal to one million electron volts.

Irradiation employs radiolysis - the splitting of water molecules into irreversible form thereby preserving the food because the water is unavailable for microbial and enzymatic activities.

The principle behind drying is that sufficient moisture is removed, which is essential for growth of microorganisms and for enzyme activity. Removal of moisture increases the storage life of the product due to reduced water activity. If the moisture content is reduced to 1 to 5 per cent then the product can be stored for more than a year. The processing should be done in such a way that the food value, natural flavour and characteristic cooking quality of the fresh foods are retained after drying. A good dried product on reconstitution with water should resemble the original product.

3.2 Learning Outcomes

By the end of this unit, you will be able to:

- Discuss food irradiation
- Write the positive and negative effects of food irradiation
- Discuss the processing of foods by moisture reduction
- Discuss the methods employed in achieving concentration of moist foods.

3.3 Biological Effects of Irradiation

The direct effects are due to the collision of radiation with atoms, resulting in an ejection of electrons from the atoms. The indirect effects are due to the formation of free radicals (unstable molecules carrying an extra electron) during the radiolysis of water molecules. The radiolysis of water molecules produces hydroxyl radicals that interact with the organic molecules present in foods. The products of these interactions cause many of the characteristics associated with the spoilage of food, such as off-flavours and off-odours.

3.3.1 Positive Effects of Irradiation

The bactericidal effect of ionizing radiation is due to damage of the bio-molecules of bacterial cells. The free radicals produced during irradiation may destroy or change the structure of cellular membranes. Radiation causes irreversible changes to the nucleic acid molecules (DNA and RNA) of bacterial cells and inhibits their growth. Pathogenic bacteria that are unable to Produce resistant endospores in foods such as poultry, meats, and seafood can be eliminated by radiation doses of 3 to 10 kilograys. If the dose of radiation is too low, then specialized enzymes repair the damaged DNA and life continues for them. If oxygen is present during irradiation, the bacteria are more readily damaged. Doses in the range of 0.2 to 0.36 kilograys are required to stop the reproduction of *Trichinella spiralis* in pork and require higher doses to eliminate it from the meat.

The dose of radiation used on food products is divided into three levels, namely:

iv. Radurisation: This is the use of low doses of ionizing radiation adequate for reducing the numbers of spoilage organisms. It is a dose of 1 to 10 kilograys that is useful for targeting specific pathogens.

v. Radicidation: The use of doses sufficient to reduce the numbers of specified viable non-sporing pathogens below detectable levels. It involves doses of less than 1 kilogray for extending shelf life and inhibiting sprouting.

vi. Radappertisation (commercial sterility): The treatment with doses of ionizing radiation sufficiently high for reducing the number of organisms below detectable levels. The range of dose is 20 to 30 kilograys and it is necessary to sterilize a food product.

3.3.2 Negative Effects

In the absence of oxygen, radiolysis of lipids causes cleavage of the inter-atomic bonds in the fat molecules, producing compounds such as carbon dioxide, alkanes, alkenes and aldehydes. Lipids are highly vulnerable to oxidation by free radicals - a process that yields peroxides, carbonyl compounds, alcohols and lactones. The consequent rancidity, resulting from the irradiation of high-fat foods is highly destructive to their sensory quality. To minimize such harmful effects, fatty foods must be vacuum-packaged and held at subfreezing temperatures during irradiation.

Proteins are not significantly degraded at the low doses of radiation employed in the food industry. For this reason irradiation does not inactivate enzymes involved in protein spoilage, as most enzymes survive doses of up to 10 kilograys. The large carbohydrate molecules that provide structure to foods are de-polymerized (broken down) by irradiation and this reduces the gelling power of the long chains of structural carbohydrates. However, in most foods other food constituents provide some protection against these deleterious effects. Vitamins A, E and B_1 (thiamine) are also sensitive to irradiation. The presence of air increases the nutritional losses of a food product during irradiation.

3.3.3 Safety Concerns

Based on the beneficial effects of irradiation on certain foods, several countries have permitted its use for specific purposes. These include the inhibition of sprouting of potatoes, onions and garlic; the extension of shelf life of strawberries, mangoes, pears, grapes, cherries, red currants, and cod and haddock fillets; as well as in the insect dis-infestation of pulses, peanuts, dried fruits, papayas, wheat and ground-wheat products. The processing room used for irradiation of foods is lined with lead or thick concrete walls to prevent radiation from escaping. The energy source, such as a radioactive element or a machine source of electrons, is located inside the room and prior to the irradiation treatment, personnel vacate the room. The food to be irradiated is then conveyed by remote means into the room and exposed to the radiation source for a predetermined time. The time of exposure and the distance between the radiation source and the food material determines the irradiation treatment. After treatment, the irradiated food is conveyed out of the room, and the radioactive element is again lowered into the water reservoir.

3.3.3.1 Advantages of Irradiation

i. Any food can be irradiated at correct doses irrespective of the state of the food (solid, liquid, gases or liquids in frozen state).
ii. The Shapes and sizes of the food item are no barriers.
iii. Irradiation can be applied to materials other than food.
Iv . It destroys parasites and enhances odour of essential oils.
v. It can be used to improve microbiological quality without significantly affecting the physical state and sensory qualities of the products.
vi. There is no risk of recontamination
vii. Most of the psychotropic microorganisms of importance to microbiological safety or keeping quality of chilled foods are relatively sensitive to radiation
viii. The incidence and contamination levels of pathogenic bacteria are usually low.
ix. It saves energy in production, distribution and marketing under ambient conditions.
xi. Irradiated foods last longer and can be accessible to a greater number of people at lower cost. xii. It enhances rural incomes since producers are able to sell a higher proportion of their product while it remains wholesome.
xiii. It improves food security especially for low income earners.

3.3.3.2 Disadvantages

i. If it is not used in the correct dose, it can lead to off-flavour.
ii. It can deposit carcinogenic matter in food that can cause malignant growth in the body. iii. It is dangerous and expensive to run.

Self- Assessment Exercises 1

1. What the disadvantages of Irradiation?
2. Discuss the positive effects of Irradiation

3.5 Preservation by Moisture Reduction

3.5.1 Drying and Dehydration

In Food Technology, drying refers to natural desiccation, such as spreading fruit on racks in the sun, and dehydration is drying by artificial means, such as a blast of hot air. Dehydration of food is an effective weapon against microbial attack, since the free water in food is essential for the proliferation of bacteria. Although the preservation of food by drying is an ancient practice, advances in Food Science and Technology have created wholly new forms, such as compressed, freeze-dried foods that resume their original shape on rehydration.

The principle behind drying is that sufficient moisture is removed, which is essential for growth of microorganisms and for enzyme activity. Removal of moisture increases the storage life of the product due to reduced water activity. If the moisture content is reduced to 1 to 5 per cent then the product can be stored for more than a year. The processing should be done in such a way that the food value, natural flavour and characteristic cooking quality of the fresh material are retained after drying. A good dried product on reconstitution with water should resemble the original product.

Foodstuffs may be dried in air, superheated steam, vacuum, or inert gas or by direct application of heat. Air is the most generally used drying medium, because it is plentiful and convenient and permits gradual drying, allowing sufficient control to avoid overheating that might result in scorching and discoloration. Air may be used both to transport heat to the food being dried and to carry away liberated moisture vapour. The use of other gases requires special moisture recovery systems.
The proteins, fats and carbohydrates in dried foods are present in larger amounts per unit weight than in their fresh counterparts, and the nutrient value of most reconstituted or rehydrated foods is comparable to that of fresh items. The biological value of dried protein is dependent on the method of drying. Some vitamins are sensitive to the dehydration process, for example, in dried meats significant amounts of vitamin C and some B vitamins (riboflavin, thiamine, and niacin) are lost during dehydration. Dried eggs, meat, milk and vegetables are ordinarily packaged in tin or aluminum containers.

In freeze-drying, a high vacuum is maintained in a special cabinet containing frozen food until most of the moisture has sublimed. Removal of water offers excellent protection against the most common causes of food spoilage. Microorganisms cannot grow in a water-free environment, enzyme activity is absent, and most chemical reactions are greatly slowed down.

Vegetables, fruits, meat, fish, and some other high moisture foods may be dried to one-fifth of the original weight and about one-half of the original volume.

The disadvantages of this method of preservation include the time and labour involved in rehydrating the food before eating. Further, reconstituting the dried product may be difficult, because it absorbs only about two-thirds of its original water content; this phenomenon tends to make the texture tough and chewy.

Proteinous foods such as meat are of good quality only if freeze-dried. Liquid food is usually dehydrated by spraying it as fine droplets into a chamber of hot air (spray drier), or occasionally by pouring it over a drum internally heated by steam (drum drier).

In-package desiccants (drying agents) improve storage stability of dehydrated white potatoes, sweet potatoes, cabbage, carrots, beets and onions and give substantial protection against browning. Retention of ascorbic acid (vitamin C) is markedly improved by packaging at temperatures up to 49°C (120°F) using either nitrogen or air a the packaging gas.

Advantages of Drying and Dehydration

viii. Low water activity, which aids food preservation.
ix. There is reduced weight compared to the initial weight of the food item, which eases packaging, storage and transportation.
x. It allows for the production of certain convenience foods e.g. tea, coffee.
xi. Dehydration/ drying are cheaper than the other methods of preservation with less requirement of equipment.
xii. Dried food products are simple to store and pack because of their low volume.
xiii. It retains the size and shape of the original food.
xiv. Dehydrated foods are less popular because of some undesirable changes in colour, taste and flavour during storage and distribution.

Factors in control of drying:

1. **Composition of raw materials:** Foods containing high amount of sugar or other solutes dry slowly.
2. **Size, shape and arrangement of stacking of produce:** the greater the surface area the greater the rate of drying.
3. **Temperature as well as humidity and velocity of air:** the greater the temperature differential between the product and the drying medium the faster it dries. Lowering the humidity of environment makes drying faster.
4. **Pressure**: the Lower the atmospheric pressure, the lower the temperature required to evaporate water.
5. **Heat transfer to surface (conductive, convective and radiative):** The fastest method of heat transfer is radiation consecutively followed by convection and conduction.

Types of Drying

Based on source of energy, drying can be done by two processes namely: natural drying and mechanical dehydration or artificial drying.

Natural drying takes place under the influence of sunlight and wind and is of three types namely: sun, solar and shade drying. In natural drying there is no control over temperature, air flow and humidity whereas in artificial drying, these conditions are well controlled.

Mechanical dehydration or artificial dehydration can be further classified into atmospheric and sub-atmospheric types based on the conditions employed in drying process. On the basis of mode of drying process, drying at atmospheric pressure conditions can be further divided into batch and continuous types.

Mechanical drying includes the methods of drying by:

(1) Heated air

(2) Direct contact with heated surface e.g. drum drying

(3) Application of energy from a radiating microwave or dielectric source.

Commercial dehydrators are generally large in size and various types of dehydrators can be based on circulation of air as:

1. Natural
2. Forced draught

In natural draught method, the rising of heated air brings about drying of food. Examples include kiln, tower and cabinet driers. Forced draught employs currents of heated air that move across the food usually in tunnels. An alternative method is to move the food or a conveyor belt or trays through heated air. Examples include tunnel or belt drier. In forced draught drier, the temperature and humidity can be carefully controlled to get a good dehydrated product but are not in general use because of the cost.

Sun drying: Drying the food product under natural sunny conditions is called as sun drying. To practice sun drying of foods, hot days are desirable with minimum temperatures of 35°C with low humidity. Poor quality produce cannot be used for natural drying to achieve good quality dried product. The lower limit of moisture content by this method is approximately 15 per cent. Problems of contamination and intermittent drying are generally encountered with sun drying. It is only possible in areas of low humidity.

Solar drying: Solar driers generate high air temperature and low humidity which results in faster drying. Solar drier is faster than sun-drying and requires less drying area but cannot be used on cloudy days.

Three types of solar driers used are:

1. The absorption or hot box type: in this type of drier the product is directly heated by sun.
2. The indirect or convection driers: in this type of drier, the product is exposed to warm air heated by a solar absorber or heat exchanger.
3. Hybrid drier which is combination of first and second type.

Shade drying: This method is used for foods which lose their colour when exposed to direct sunlight for drying. Examples of foods dried using shade drying include herbs, green and red chilies, okra, beans, etc.

A home scale dehydrator or drier: this device consists of a small galvanized box with a dimension of 90x90x60 cm. The material to be heated is kept on trays and heating source can be a gas stove or any other source. The initial temperature of the dehydrator is usually is 43°C which is gradually increased to 60-66°C in the case of vegetables and 66-71°C for fruits. For a home scale drier 100-200 g of sulphur is required for 25 kg fruit. The time required for this type of drying is generally 30 minutes to 2 hours.

Oven drying: This is a kind of cabinet drier and a conventional oven drier with a thermostatic setting of 60°C is suitable for oven drying of fruits, vegetables, fruit, leathers, and meats.

Kiln drier (kiln evaporator): Kiln drier consists of two floors, food to be dried is spread on the top floor and the furnace is housed on the lower floor. In Kiln drier, heat is conveyed by a ventilator and it is used for large pieces of food.

Belt-trough drier: In Belt-trough drier, belt is in the form of a trough, which is made of metal mesh. Hot air is blown through the mesh and food pieces lying on the trough are dried in the process.

Spray drying: Spray drier is used to dry purees, low viscosity pastes, and liquids which can be atomized. The food is sprayed in a rapidly moving current of hot air and the dried product drops to the bottom of the drying chamber and is collected. Atomization into minute droplets results in drying in a matter of seconds with common inlet air temperature of about 200°C and a properly designed system quickly removes the dried particles from heated zones. This method of dehydration can produce exceptionally high quality with many highly heat sensitive materials including milk and coffee.

Microwave drying: This method uses microwaves to dry the food product.

Freeze drying: Foods in the pieces and liquids are dried by this method. Fruit juice concentrates are manufactured using freeze drying. The material is frozen on trays and then dried under vacuum. In vacuum drying, the material dries directly without passing through the intermediate liquid stage. The principle behind freeze drying is that under certain conditions of low vapour pressure, water can evaporate from ice without the ice melting. Freeze drying is used to dry sensitive and high value liquid as well as solid foods such as juices, coffee, strawberries, chicken dice, mushroom slices etc. The dried product is highly hygroscopic and reconstitutes readily. Taste, flavour and reconstitution property of fruit juice concentrates are excellent. This method is cost intensive. Freeze drying in combination with air drying is advantageous in reducing cost of drying. For example, vegetables pieces may be air dried to about 50 per cent moisture and then freeze dried down to 2-3 per cent moisture.
The disadvantages of freeze drying are that cooked flavour might result and it can also cause darkening of the food item.

3.5.2 Concentration of Moist Foods

This is the partial removal of water from a food item, giving rise to a syrup-like product. Food items such as syrups, evaporated milk, tomato ketchup and condensed soups are examples of concentrated food item. The methods employed in achieving concentration of moist food are:

i. **The kettle method:** This method involves the use of open kettles or pans. It is of benefit in foods where caramelization is desirable such as malt drink, stout, etc.
ii. **Flash method:** This process is commonly used for purees and it involves the application of superheated steam to the food items in steam jackets.
iii. **Film method:** This involves pumping the food into a heated vertical cylinder to produce a film of the food which gets dry fast.
iv. **Vacuum method:** This is applied to heat sensitive foods.
v. **Freeze concentration method:** This involves the removal of frozen water from food items via sublimation.
vi. **Ultra-filtration and reversed osmosis:** This process involves the use of a selectively permeable membrane, which filters and leaves the macromolecules.

Self- Assessment Exercises 2

1. What are the factors in control of drying?
2. List the Three types of solar driers used in food preservation

3.6 Summary

Food irradiation is safer than fumigation of Foods but nonetheless it has advantages and disadvantages. Food Preservation and processing can also be achieved either by reduction in moisture contents or concentration of moist foods.

Irradiation of foods is a useful tool for control of the presence of food borne non-spore-forming pathogenic bacteria and microorganisms. There are serious biological effects of food irradiation, some of whichh are advantageous while others are undesirable. Preservation of foods is achieved by moisture reduction and concentration of msoist foods.

3.7 References/Further Readings

FSIS. (1996). FSIS Pre-HACCP Standard Sanitation Operating Procedures Reference Guide. Food Safety and Inspection Service, U.S. Department of Agriculture. 50 pages

Gardner, S. (1993). Consumers and Food Safety: A Food Industry Perspective. In Food, Nutrition, and Agriculture – Consumer Participation in Food Control.

Improving the Safety and Quality of Fresh Fruits and Vegetables: A Training Manual for Trainers. United Nations New York and Geneva, 2007 http://www.fao.org/docrep/v2890t/v2890t00.htm. 140 pages

Gould, W.A. and Gould, R.W (1993). Total Quality Assurance for the Food Industries. 2nd ed. CTI Publications, Baltimore, MD, USA.

Satin, M. (1996). *Food Irradiation: A Guidebook*, 2nd edition. Lancaster, PA: Technomic Publishing.

FDA. (1998). Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables. http://www.cfsan.fda.gov/~dms/prodguid.html .

FDA. (2001). FDA Publishes Final Rule to Increase Safety of Fruit and Vegetable Juices. http://www.fda.gov/bbs/topics/NEWS/2001/NEW00749.html
.

3.8 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. Disadvantages of Irradiation

i. If it is not used in the correct dose, it can lead to off-flavour.
ii. It can deposit carcinogenic matter in food that can cause malignant growth in the body. iii. It is dangerous and expensive to run.
2. The bactericidal effect of ionizing radiation is due to damage of the bio-molecules of bacterial cells. The free radicals produced during irradiation may destroy or change the structure of cellular membranes. Radiation causes irreversible changes to the nucleic acid molecules (DNA and RNA) of bacterial cells and inhibits their growth. Pathogenic bacteria that are unable to Produce resistant endospores in foods such as poultry, meats, and seafood can be eliminated by radiation doses of 3 to 10 kilograys. If the dose of radiation is too low, then specialized enzymes repair the damaged DNA and life continues for them. If oxygen is present during irradiation, the bacteria are more readily damaged. Doses in the range of 0.2 to 0.36 kilograys are required to stop the reproduction of *Trichinella spiralis* in pork and require higher doses to eliminate it from the meat.

Answers to Self-Assessment Exercises 2

1. Factors in control of drying:

1. **Composition of raw materials:** Foods containing high amount of sugar or other solutes dry slowly.
2. **Size, shape and arrangement of stacking of produce:** the greater the surface area the greater the rate of drying.
3. **Temperature as well as humidity and velocity of air:** the greater the temperature differential between the product and the drying medium the faster it dries. Lowering the humidity of environment makes drying faster.
4. **Pressure**: the Lower the atmospheric pressure, the lower the temperature required to evaporate water.
5. **Heat transfer to surface (conductive, convective and radiative):** The fastest method of heat transfer is radiation consecutively followed by convection and conduction.

2. **Three types of solar driers used are:**

1. The absorption or hot box type: in this type of drier the product is directly heated by sun.
2. The indirect or convection driers: in this type of drier, the product is exposed to warm air heated by a solar absorber or heat exchanger.
3. Hybrid drier which is combination of first and second type.

UNIT 4 FOOD PRESERVATION PROCESS III: USE OF ADDITIVES, MODIFIED ATMOSPHERE AND FERMENTATION

CONTENTS

4.1 INTRODUCTION

Food Additives are compounds that are added to foods as an aid to processing, improving the keeping qualities, flavour, colour, texture, appearance and stability of the food. Vitamins, minerals and other nutrients added to fortify or enrich the food are generally excluded from the definition of additives, as well as herbs, spices, salt and yeast or protein hydrolysates commonly used to enhance flavour.
Preservatives are the chemical agents which serve to retard, hinder or mask undesirable changes in food this is achieved by retarding, inhibiting or arresting the activities of microorganisms such as fermentation, acidification and decomposition of food or of masking any

of the evidence of putrefaction but it does not include salt, sugar, vinegar, glycerol, alcohol, spices, essential oils etc.

Preservatives may be anti-microbial preservatives, which inhibit the growth of bacteria and fungi, or antioxidants such as oxygen absorbers, which inhibit the oxidation of food constituents. Common anti-microbial preservatives include calcium propionate, sodium nitrate, sodium nitrite and sulfites (sulfur dioxide, sodium bisulphite, potassium hydrogen sulphite, etc.) and ethylenediamine tetra acetic acid (EDTA). Antioxidants include butylated hydroxy anisole (BHA) and butylated hydroxy toluene (BHT).

Sulphur dioxide and benzoic acid are among the major preservatives used in the food processing industry.
Chemical preservatives are food additives specifically added to prevent the deterioration or decomposition of a food. Preservation of foods by the chemicals is affected by interfering with the cell membrane of the microorganism, their enzyme activity and genetic mechanism; and by acting as antioxidants.

Where laboratory testing has shown that high intake of an additive has adverse effects on experimental animals, the amount that may be used is controlled by law to ensure that the total intake from all foods in a daily diet is within a safe range. This acceptable daily intake (ADI) is usually one- hundredth of the highest dose that has no detectable effect in laboratory tests. Compounds for which no adverse effects can be detected, even using extremely high levels of intake, are classified as "ADI not determined", and may be used without any limitation, although the intensity of colour and flavour will usually limit the amount that is used. Additives are classified by their function and it includes:

Class I preservatives: This class I is considered to be relatively safe to humans and includes the use of sugar, salt, spices, acetic acid and alcohol.
Class II preservatives: This is considered to be relatively safe to humans, but within the permissible doses prescribed by the food regulatory bodies of the country because higher concentrations can be a health hazard and they includes the use of benzoic acid, sulfur dioxide, nitrates and nitrites and a variety of neutralizers, firming agents and bleaching agents.

Permitted usage levels of chemical preservatives in foods

Foods	**Chemical preservative**	**Concentration (ppm)**
v. Nectars, ready to serve beverages in bottles/pouches selling through dispenser. vi. Fruit juice concentrates with preservatives for conversion in juices, nectars for ready to serve beverages in bottles/ pouches selling through dispensers. vii. Fruit juices (tin, bottles or pouches) viii. Jams, jellies, marmalades, preserve, crystallized glazed or candied fruits including candied peels fruit bars	Sorbic acid and its salts (calculated as sorbic acid)	50 100 200
vi. Ready to serve beverages. vii. Jam, marmalade, preserved canned cherry and fruit jelly. viii. Pickles and chutneys made from fruits or vegetables. ix. Squashes, crushes fruit syrups, cordials, fruit juices and barley water or to be used after dilution; Syrups and sherbets. x. Tomato and other sauces; Tomato puree and paste	Benzoic acid and its salts	120 200 250 600 750
v. Jam, marmalade, preserved canned cherry and fruit jelly. vi. Crystallized glace or cured fruit (including candied peel) vii. Squashes, crushes fruit syrups, cordials, fruit juices and barley water or to be used after dilution; Syrups and sherbets; Fruit and fruit pulp. viii. Dehydrated vegetables	Sulphur dioxide	40 150 350 2000
Pickled meat	Sodium and / or Potassium nitrite expressed as Sodium nitrite	200
Fermented meat, dairy and vegetable products, sauces and dressings, drinks.	Lactic acid	No limit

Fruit juices; jams; other sugar preserves	Citric acid	No limit
Vegetable pickles; other vegetable sauces, chutney	Acetic acid	No limit

4.2 Learning Outcomes

By the end of this unit the student should be able to:

- Analyse "food additive"
- Discuss the additives according to functions
- Discuss the use of modified technology to improve qualities of foods
- Analyse the types of fermentation of foods.

4.3 Types of Additives

4.3.1 Colourants

These refer to a range of organic compounds either synthetic chemicals or naturally occurring plant pigments, namely: chlorophyll, carotenoids and anthocyanins that may be added to foods to enhance the colour. When a desirable food process leads to a loss of colour from the food, or a new product looks unduly insipid, the processor wisely takes steps to make it more attractive through the use of food grade colours. Some mineral salts can also be used as colours salts of calcium and iron which enhance the nutritional value of the food as well as its colour.

4.3.2 Preservatives

The Food and Drug Administration defines a chemical preservative as "any chemical that when added to food, tends to prevent or retard deterioration, but does not include common salt, sugars, vinegars, spices or oils extracted from spices, substances added to food by direct exposure thereof to wood smoke or chemicals applied for their respective insecticidal or herbicidal properties".

The ideal chemical preservative must be able to inhibit the growth of moulds, yeasts and bacteria. It must be non-toxic to test animals and ultimately to humans. It should be capable of been metabolized by the body and not subject to further detoxification procedure in the liver. There should not be a residue build-up in fatty tissue. Ideally, it should be water-soluble because if it is fat-soluble, it might be unavailable for antimicrobial action, since micro-organisms grow in the aqueous phase. It should be stable in the food product and not react with other additives or natural components of food. It should exhibit no taste, odour or colour. It should be cheap and be able to pay for itself by reducing spoilage and minimizing food borne illness.

Preservatives are used to protect foods against the growth of microorganisms that might cause spoilage or food poisoning, and so increase the safe storage life of the product. Such compounds include sorbic and benzoic acids and their salts, sulphur dioxide and its salts, as well as nitrites and nitrates used in pickling salts. The following is a review of commonly used preservatives.

a. Benzoates

The optimum pH range for antimicrobial activity by benzoates is 2.5 – 4.0, which is lower than that for sorbate or propionate. Sodium benzoate has activity against yeast, mould and bacteria but is not usually recommended for bacterial control because of its decreased activity above pH 4.5, where bacteria are the greatest problem. The lower pH range makes benzoates well suited for the preservation of foods that are acidic or readily acidified, such as carbonated beverages, fruit juices and pickles. FDA regulations generally recognize benzoates as safe for use in foods with a maximum level of 0.1%. Benzoates are cheap compared to other antimicrobial additives.

b. Parabens

The antimicrobial property of parabens is directly proportional to its chain length but solubility decreases with increase in chain length. Usually, a combination of methyl and propyl esters are often used. The parabens are not water-soluble and are most active against gram-negative bacteria. The parabens are more costly than other preservatives. The methyl and propyl ester are considered GRAS with a maximum total use level of 0.1%. They are used in cakes and fillings, soft drinks, fruit juices and salads, and artificially sweetened jams and jellies. A maximum level of 12 ppm heptyl ester is used in beer.

h. Propionates

Propionates were among the first monocarboxylic fatty acids to be used as an antimicrobial agent in foods. Propionates have good antimicrobial activity against moulds but little against yeasts and bacteria. They are considered as GRAS for use in foods and have no upper limits except in products like bread, rolls and cheese. Calcium and sodium propionate are equally effective, but the calcium salt is used in breads and rolls because of the enrichment contribution of calcium. The sodium salt is used in chemically leavened products because the calcium ion interferes with the leavening action.

i. Sorbates

Sorbic acid is slightly soluble in water but potassium salt is very water-soluble (up to 139g/100ml at 25°C). The optimum pH range of effectiveness extends up to pH 6.5, higher than the upper range of benzoates and propionates but below that of parabens. Sorbates are used to preserve cheese products, baked foods, beverages, syrups, fruit juices, wines, jellies, jams, salads, pickles, margarine and dried sausages. Sorbates are considered as GRAS and have been used traditionally as antifungal agent in foods and food wrappers to control yeasts and moulds. Being a fatty acid, sorbates are metabolised by the body to carbon dioxide and water. Sorbates are cheap and are usually used in lower quantities than the cheaper benzoates and propionates in the higher-pH products to achieve the desired effect.

j. Acetates

Some derivatives of acetic acid such as monochloroacetic acid, peracetic acid, dehydroacetic acid and sodium diacetate have been recommended as preservatives, but not all are approved by the FDA. Dehydroacetic acid has been used to impregnate wrappers for cheese to inhibit the growth of moulds and as a temporary preservative for squash. Acetic acid in the form of vinegar is used in mayonnaise pickles, catsup and pickled sausages. Acetic acid is more effective against yeast and bacteria than moulds, and its effectiveness increases with a decrease in pH. Sodium diacetate has been used in cheese spreads, malt syrups and as treatment for wrappers used on butter.

k. Sulphites

Sulphurous acid, the active antimicrobial compound is formed by sulphur dioxide, sulphite salts, bisulphate salts and metabisulphite salts in aqueous solutions. The effectiveness of sulphurous acid is enhanced at low pH values. The fumes of burning sulphur are used to treat most light- coloured dehydrated fruits, while dehydrated vegetable are exposed to a spray of neutral bisulphite and sulphites before drying. Sulphur dioxide has also been used in syrups, fruit juices and wine making. sulphites can also be used on meat and fish.

Sulphites are also used to prevent enzymatic and non-enzymatic changes or discolouration in some foods in addition to its antimicrobial action. They are most effective against yeasts, moulds and bacteria. However, current levels are limited because at about 500 ppm the taste becomes noticeable. SO_2 and several sulphite salts are considered GRAS, but they may not be used in foods which have substantial amounts of thiamine. Bisuphites also degrade aflatoxin B_1 and G_1 in addition to its antimicrobial action.

l. Nitrites and Nitrates

Combinations of nitrite and nitrate salts have been used in curing solutions and curing mixtures for meats. Nitrites decompose to nitric acid, which forms nitrosomyoglobin when it reacts with the heme pigments in meats and thereby forms a stable red colour. Nitrates only act as a reservoir for nitrite and its use is being restricted. Nitrites can react with secondary and tertiary amines to form nitrosamines, which are known to be carcinogenic. The problem of possible carcinogenic nitrosamines appears to be greatest in cured meat from the back or sides of pig (bacon). The extended future for the use of nitrites in foods is therefore questionable and at least controversial. They are currently added in the form of sodium nitrite, potassium nitrite, sodium nitrate, or potassium nitrate. Studies have demonstrated the inhibitory property of nitrites toward *Clostridium botulinum* in meat products, particularly in bacon and canned or processed hams.

4.3.3 Smoke

The smoking of foods usually has two main purposes, adding desired flavours and preserving. Other desirable effect that may result includes: improvement in the colour of the inside of meat and in the finish, or “gloss” of the outside and a tenderising action on meats. Normally, smoke is obtained from burning wood, preferably a hard wood like hickory, but may also be generated from burning corn cobs or other materials or woods like apple, oak, maple, beech, birch, walnut and mahogany.

Preservative action is provided by bactericidal chemicals in the smoke such as formaldehyde, guaiacol (2-methoxyphenol), and creosote, which has limited bactericidal and antioxidant action and by the dehydration that occurs in the smokehouse. Wood smoke contains a large number of volatile compounds that differ in their bacteriostatic and bactericidal effect. Wood smoke is more effective against vegetative cells than against bacterial spores and the rate of germicidal action of the smoke increase with its concentration and the temperature and varies with the kind of wood employed. The residual effect of the smoke in the food has been reported to be greater against bacteria than against moulds. The application of “liquid smoke”, a solution of chemicals similar to those in wood smoke, to the outside of foods has little or no preservatives effect although it contributes to flavour.

4.3.4 Sugar and Salt

Sugar and Salt tend to tie up moisture and thus have adverse effect on microorganisms. The adverse effects of Salts on foods are:

1. It causes high osmotic pressure and hence plasmolysis of cells; however, the percentage of salt necessary to inhibit growth or harm the cell varies with the micro-organism.
2. It dehydrates foods by drawing out and tying up moisture as it dehydrates microbial cells.
3. It ionizes to yield the chlorine ion which is harmful to organisms
4. It reduces the solubility of oxygen in the moisture
5. It sensitizes the cell against carbon dioxide
6. It interferes with the action of proteolytic enzymes.

   Sugars like glucose or sucrose are effective as preservatives due to their osmotic effect and ability to make water unavailable to organisms. Examples of foods preserved by high sugar concentrations are sweetened condensed milk, fruits in syrups, jellies and candies.

4.3.5 Formaldehyde

The addition of formaldehyde to foods is not permitted, except, as a minor constituent of wood smoke. Formaldehyde is effective against moulds, bacteria and viruses and can be used where its poisonous nature and irritating properties are not objectionable. It is useful in the treatment of walls, shelves, floors, etc to eliminate moulds and their spores.

4.3.6 Antioxidants

Antioxidants are used to prevent rancidity in fatty foods and to protect the fat- soluble vitamins against damage by oxidation. Synthetic antioxidants include esters of gallic acid, tertiary butylhydroquinone (TBHQ), butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA). BHA and BHT are not permitted in baby foods while L-Ascorbic acid is preferred for moist foods, such as meat, bakery products and beer. Vitamins C and E are also used as antioxidants; they clearly enhance the nutritional value of the food to which they are added. Some spices have value as antioxidants, but their main function is flavour enhancement just like the additive monosodium glutamate.

4.3.7 Acidity Regulators (Acidulants)

Acidulants act to reduce the pH, minimize microbial growth and enhance the effect of the weak acid preservatives. Alkalis, including sodium, potassium, calcium, and magnesium hydroxides, may be used to neutralize excess acidity in foods. Acids and their salts are used as flavourings and also to control the pH of foods. Acetic acid, lactic acid , propionic, malic and fumaric acids, also have valuable antimicrobial action, and may, in addition, be classified as preservatives. Others, including ascorbic (vitamin C), citric, tartaric, phosphoric, hydrochloric, sulphuric acids and their salts, as well as carbon dioxide and carbonates or bicarbonates may be used either as buffers or for special purposes, including acting as emulsifying agents, raising agents or anticaking agents.

4.3.8 Emulsifiers and Stabilizers

An emulsifier is a substance which aids the formation of a stable mixture of two immiscible substances such as fat and water. A stabilizer helps to maintain an emulsion when it is formed. The stabilizer may have the same basic characteristic with an emulsifier, or it may serve to thicken one or more participant in the emulsion, or make it more viscous and hence less likely to separate into its components. Additives in this group are used to enable oils and fats to mix with water and to form smooth emulsions (example margarine and mayonnaise), to give a smooth creamy texture to foods, and to slow the staling of baked goods. A variety of plant gums, including alginates, agar, guar gum, and carob gum, may make a useful contribution to the intake of non- starch polysaccharide (dietary fibre), as may pectins and the various cellulose derivatives that are widely used. Lecithin and a variety of salts and esters of fatty acids are also emulsifying agents
.

4.3.9 Anticaking Agents

These are anhydrous substances that can pick up moisture without themselves becoming wet. In other words, they immobilize moisture coming in contact with a food material. They are added to particulate products, such as dry mixes, to prevent the particles from clumping together and so keeps the product free flowing. Anticaking agents are used to ensure that powders such as flour or salt remain free flowing. compounds that are used as anticaking agents include bone meal, polyphosphates, silicates, stearates, gluconates, salts of long chain fatty acids (such as myristic, palmitic and stearic).

4.3.10 Humectants

They are required to keep certain food products moist as in bread and cakes. Humectants pass any incoming moisture into the product to compensate for losses due to natural drying. All humectants are hygroscopic in nature. Commonly used humectants include glycerol, sorbitol and propan-1, 2-diol.

4.3.11 Sequestrants

Metals like copper and iron can act as pro-oxidant catalyst and therefore need to be immobilized. Sequestrants are compounds added to do just that and they include EDTA, phosphates, tribasic citric acid, tartaric acid and its salts.

4.3.12 Flavouring Agents

These include sweeteners, some fruit acids, natural extracts of fruits and herbs, and synthetic compounds designed to mimic natural flavours. A number of compounds such as glutamic acid and its salts (especially monosodium glutamate), and nucleic acid derivatives are used to enhance the flavour of foods, without giving any particular flavour of their own.

Self- Assessment Exercises 1

1. State the adverse effect of salt on food
2. Discuss the important of humectant in food industry

4.4 Use of Modified Atmospheres

The normal composition of air is 20% oxygen (O_2), 79% nitrogen (N_2) and 1% carbon dioxide (CO_2). A modified atmosphere (MA) is one in which the normal composition of air around a food material is changed or "modified" at the point of packing. This modification usually results in a reduction of the O_2 content of air while increasing the level of CO_2 and N_2. A controlled atmosphere (CA) is a process whereby the gaseous environment is modified to a desired level and controlled at that level, with strict limits, throughout storage and usually applied to bulk storage products. A modified atmosphere applies to food packaged in small convenient retail units in which the gaseous atmosphere is modified or changed at the point of packing.

4.4.1 Vacuum Packaging

This is the most common method of modifying the internal package environment and is used extensively by the meat industry to extend the shelf life and keeping quality of fresh meat. The product is placed in a film of low oxygen permeability, air is evacuated and the package is sealed. Under conditions of a good vacuum, headspace O_2 is reduced to <1% while CO_2, produced from tissue and microbial respiration, eventually increases to 10-20% within the package headspace. These conditions, i.e. low O_2 and elevated CO_2 levels, help extend the shelf life of meat by inhibiting growth of normal aerobic meat spoilage microorganisms particularly *Pseudomonas* and *Altermonas* species.

The shelf life of a vacuum packaged meat depends on a number of inter-related factors; specifically the microbiological quality and pH of meat at time of packing; packaging film permeability, package integrity and storage temperature. The main disadvantage of vacuum packaging from a commercial viewpoint is that the depletion of oxygen, coupled with the low oxygen permeability of the packaging film, results in a change of meat colour from red to brown. Vacuum packaging cannot be used on soft products such as pizza, pasta or baked products.

4.4.2 Gas Packaging

Gas Packaging involves packaging of product under an atmosphere of various gases such as CO_2, N_2, O_2 and sometimes CO but the most commonly used and perhaps the most effective is CO_2 with or without other gases. For example, with meat O_2 is necessary for the bright red colour or "bloom" which is associated with good quality meat but O_2 also promotes microbial growth. Carbon dioxide is a bacteriostatic agent, but it will discolour fresh meat. The problem of balancing these two separate effects can be overcome by using a mixture of gas incorporating CO_2, O_2 and N_2. The N_2 is needed to prevent the packaging film collapsing around the product as CO_2 dissolves the meat. The major advantages of gas packaging are: increased shelf life, increased market area, reduction in production and storage costs, reduction in use of inhibitors, improved presentation, fresh appearance, clear view of product and easy separation of slices. Some of its disadvantages include high initial cost of packaging equipment, films, etc; discolouration of meat pigments, leakage, and fermentation by CO2 resistant microorganisms, swelling and potential growth of organisms of public health significance

4.4.3 Oxygen Absorbants

Oxygen absorbants consist of iron oxide packaged in small sachets like a desiccant (sold under the trade name "ageless") and come in a variety of sizes that absorb 20 – 2000 cc of oxygen. When used in conjunction with a film of low oxygen permeability, the headspace O_2 is reduced to less than 0.05% within hours in the packaged product and remains at this level for the duration of the storage period. Oxygen absorbants have been widely used in Japan to extend the mould-free shelf life of bread, pizza crusts and cakes as well as prevent oxidation of fats in potato chips, dried fish, beef jerky, semi-moist cookies and chocolates.

4.4.4 Ethanol Vapour Generators

Ethanol is widely used as a germicidal agent but few studies have evaluated ethanol as a food preservative. A novel and innovative method of generating ethanol vapour, is through the use of ethanol vapour generators, sold under the trade name "ethicap". Ethicap comprises of a paper/ethyl vinyl acetate sachet containing food grade ethanol adsorbed onto a fine silicon dioxide powder. When a food is packed with a sachet of ethicap, moisture is absorbed from the food and ethanol vapour is released from encapsulation and permeates the package headspace. Ethanol vapours are extensively used in Japan to extend the shelf life of high moisture baked products.

4.5 Fermentation and Pickling

Fermentation is a process of anaerobic or partial anaerobic oxidation during which enzymes from microorganisms or the food material break down carbohydrates or carbohydrate-like material into simpler substances. It may also be defined as an ATP generating metabolic process in which organic compounds serve both as electron donors and as electron acceptors. Fermentation may be separated into that caused by microorganisms and those influenced by enzymes. However, only those products involving the deliberate fermentative growth of microorganisms are described as being fermented. Products whose manufacture primarily involves the activity of indigenous or added enzymes are better referred to as being enzyme hydrolyzed. In cases where the hydrolysis is purely due to indigenous enzymes, this will be properly described as autolysis.

Normally, fermentation results in the breakdown of complex organic substances into simpler ones through catalysis. For example, by the action of diastase, zymase, and invertase, starch is broken down (hydrolyzed) into complex sugars, then simple sugars and finally alcohol. Fermentation is employed in the processing of some food items like burukutu, bread, milk products, matured palm wine, beer etc.
It seems quite contradictory that microorganisms and enzymes, which are known to be responsible for food spoilage and deterioration, are also used for food preservation. Microorganisms and enzymes are able to achieve this due to the following reasons:

The environment of the food item is saturated with the fermenting organisms which lower the pH and prevent entry of other microorganisms. As the pH is reduced, preservation is ensured. Macromolecules in the food would have been broken down into macromolecules which can no longer be attacked by microorganisms. They produce alcohols, acids etc which are capable of preserving the food. The keeping quality of alcoholic beverages depends on the percentage of ethanol produced. The higher the percentage produced, the longer the shelf life.

The action of certain bacteria on undigested carbohydrates causes fermentation in the human intestine producing gases such as hydrogen sulphide and carbon dioxide in amounts large enough to cause distension and pain. Acids such as lactic acid and ethanoic acid may also form in the intestines of infants, causing diarrhoea.

Pickling deals with preservation of food materials, especially vegetables, in brine, vinegar and mustard. The process results in absorption of salts, which in turn, result in removal of water from the flesh to a level that impedes microbial growth and enzyme activities. Fresh fruits and vegetables soften after 24 hours in a watery solution and begin a slow, mixed fermentation-putrefaction process. The addition of salt suppresses undesirable microbial activity, creating a favourable environment for the desired fermentation. Pickling may therefore be used to preserve most green vegetables and fruit.

Meat may be preserved by dry curing or with a pickling solution. The ingredients used in curing and pickling are sodium nitrate, sodium nitrite, sodium chloride, sugar, and citric acid or vinegar.

Various methods are used: the meat may be mixed with dry ingredients; it may be soaked in pickling solution; pickling solution may be pumped or injected into the flesh; or a combination of these methods may be used. Curing may also be combined with smoking. Smoke acts as a dehydrating agent and coats the meat surfaces with various chemicals, including small amounts of formaldehyde.

Fermented foods and pickled products require protection against moulds which metabolize the acid developed and allow the advance of other microorganisms. Fermented and pickled food products placed in cool storage remain stable for several months. Longer storage periods demand more complete protection (such as canning). Nutrient retention in fermented and pickled products is about equal to retention for products preserved by other methods or increased because of the presence of yeasts.

4.5.1 Types of Fermentation

An important type of fermentation is alcoholic fermentation, in which the action of zymase secreted by yeast converts simple sugars, such as glucose and fructose, into ethyl alcohol and carbon (iv) oxide. Many other kinds of fermentation occur naturally, as in the formation of butanoic acid when butter becomes rancid and of ethanoic (acetic) acid when wine turns to vinegar.

Alcoholic Fermentation

Alcoholic fermentation involves the use of yeast to breakdown glucose into alcohol and carbon (iv) oxide. This step is involved in the alcoholic fermentation of starchy foods by species of *Saccharomyces* (*carlsbergensis* or *cerevisiae*). It is applied in the brewing industry where beer and similar cereal beverages that undergo fermentation are produced.

Acetic Acid Fermentation

This involves the conversion of ethanol into acetic acid by *Acetobacter*. This step is involved in the souring of wine.

Lactic Acid Fermentation

Lactic acid is usually prepared by fermentation of lactose, starch, cane sugar or whey. This acid, generated in milk by fermentation of lactose, causes the souring of milk. The lactic acid bacteria, as presently constituted, consists of the following four genera *Lactobacillus*, *Leuconostoc*, *Pediococcus* and *Streptococcus*. They all share the property of producing lactic acid from hexose sugars. Lactic acid is used in preparing cheese, sauerkraut, soft drinks, and other food products. In this type of fermentation, glucose is converted to lactic acid by *Lactobacillus*. Lactic acid fermentation is employed in dairy for the production of sour milk products.

Self- Assessment Exercises 2

1. List the ingredients used for curing and pickling of meat

2. Explain the major advantages of gas packaging of foods

4.6 Summary

The food industries employ many methods to improve the qualities of their products including: the use of additives to improve colour, flavour and shelf life, the use of modified atmosphere to create conducive environment for the non-growth of microorganisms and the use of various preservatives to prevent spoilage

Additives are used extensively in the food industry to improve colour, flavour and preservation.

Modern biotechnology can be applied in (a) fermentation (b) vacuum packaging and (c) gas packaging to improve the shelf life and qualities of meat and beverages.

4.7 Glossary

Asepsis: a process of keeping microorganisms out of food.

Drying: removal of water from food and is one of the oldest and simplest methods of preserving food.

Refrigeration: process of lowering the temperature in a given space and maintaining it for the purpose of chilling foods, preserving certain substances, or providing an atmosphere conducive to bodily comfort.

Regeneration: A process in which food is returned to its original state for eating after chilling.

4.7 References/Further Readings

USDA. (2000). Fruit and Vegetable Programs. www.ams.usda.gov/fv/fvstand.htm

U.S. EPA. (2001). Guidance for Preparing Standard Operating Procedures. Office of Environmental Information, U.S. Environmental Protection Agency. EPA/240/B-01/004. http://www.epa.gov/quality1/qs- docs/g6-final.pdf

van Reeuwijk, L.P. (1998). Guidelines for quality management in soil and plant laboratories. FAO, Rome. Publication #M-90. http://www.fao.org/docrep/w7295e/w7295e00.htm

Wilson, L.G., Boyette, M.D., and Estes, E.A. (1995). Postharvest handling and cooling of fresh fruits, vegetables, and flowers for small farms. Part I: Quality maintenance. Horticultural Information Leaflet #800, North Carolina Cooperative Extension Service. http://ces.ncsu.edu/depts/hort/hil/hil-800.html

ASQ. (2000). ISO 9000 Standards for Quality. Amer. Soc. Qual. http://www.iso-9000-2000.com

Boutrif, E. and Bessy, C. (1999). Basic Approaches to consumer Protection – FAO/WHO Model Food Act – Control Procedures. Presented at Conference on International Food Trade – Beyond 2000: Science-based Decisions, Harmonization, Equivalence, and Mutual Recognition, Melbourne, Australia October 11-15.

Codex (2000). Codex Committee on Fresh Fruits and Vegetables. http://www.codexalimentarius.net

FAO. (1989). Prevention of Post-Harvest Food Losses: Fruits, Vegetables, and Root Crops a Training Manual. FAO Training Series No. 17/2, Rome, Italy. http://www.fao.org/inpho/vlibrary/t0073e/T0073E00.htm

FAO/WHO. (1997). Codex Alimentarius Food Hygiene Basic Texts. Joint FAO/WHO Food Standards Programme, Codex Alimentarius Commission. Pub. # M-83.

FDA. (1998). Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables. U.S. Food and Drug Administration. http://www.cfsan.fda.gov/~dms/prodguid.html

4.8 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. The adverse effects of Salts on foods are:

- It causes high osmotic pressure and hence plasmolysis of cells; however, the percentage of salt necessary to inhibit growth or harm the cell varies with the micro-organism.
- It dehydrates foods by drawing out and tying up moisture as it dehydrates microbial cells.
- It ionizes to yield the chlorine ion which is harmful to organisms
- It reduces the solubility of oxygen in the moisture
- It sensitizes the cell against carbon dioxide
- It interferes with the action of proteolytic enzymes.

2. **Humectants** are required to keep certain food products moist as in bread and cakes. Humectants pass any incoming moisture into the product to compensate for losses due to natural drying. All humectants are hygroscopic in nature. Commonly used humectants include glycerol, sorbitol and propan-1, 2-diol.

Answers to Self-Assessment Exercises 2

1. The ingredients used in curing and pickling are sodium nitrate, sodium nitrite, sodium chloride, sugar, and citric acid or vinegar.
2. The major advantages of gas packaging are: increased shelf life, increased market area, reduction in production and storage costs, reduction in use of inhibitors, improved presentation, fresh appearance, clear view of product and easy separation of slices. Some of its disadvantages include high initial cost of packaging equipment, films, etc; discolouration of meat pigments, leakage, and fermentation by CO_2 resistant microorganisms, swelling and potential growth of organisms of public health significance.

MODULE 5

UNIT 1 DETERIORATION AND SPOILAGE OF FOODS

CONTENTS

1.1 INTRODUCTION

Spoilage of food refers to any visible or invisible change which can makes food or product derived from food unacceptable for human consumption. Spoilage of food not only causes health hazard to the consumer but also cause large economic losses. Spoilage not only leads to loss of nutrients from food but also causes change in original flavour and texture. It is estimated that about 25% of total food produced is spoilt due to microbial activities only despite range of preservation methods available. Hence, the spoilage of food is not only a health hazard but also carry lot of economic significance too.

In all, the food spoilage is considered a complex phenomenon whereby a combination of microbial and biochemical activities take place leading to the production of various types of metabolites which aid in spoilage.
All foods undergo varying degrees of deterioration after harvest and during storage, leading to losses in nutritional value, safety, and esthetic appeal (colour, texture, flavour). Fruit, vegetables and root crops are very perishable and, if care is not taken in their harvesting, handling and transport, they will soon decay and become unfit for human consumption. Estimates of production losses in developing countries are hard to judge, but some authorities put losses of sweet potatoes, plantain, tomatoes, bananas and citrus fruit as high as 50 percent of what is grown. Reduction in these losses, particularly if they can be avoided economically, would be of great significance to growers and consumers alike.

All fruits, vegetables and root crops are living plant parts containing 65 to 95 percent water and they continue their life processes after harvest. The post-harvest life of produce depends on the rate at which stored food reserves are used up and the rate of water loss. The changes that occur not only lead to reduced quality but can also make the product more susceptible to contamination with microorganisms.
Food by nature is subject to deterioration either by chemical or microbial means. The shelf-life will be influenced by factors such as:

1. Nature of the product (nutritional composition)
2. Packaging
3. Temperature

In order to optimize the storage quality and extend shelf-life of fresh and value-added products, a clear understanding of the role of the following factors in food spoilage is important:

i. chemical components in the food
ii. environmental conditions
iii. initial microbial load
iv. nature and types of microorganisms present

Deterioration, or undesirable quality changes, may be the result of biological, microbiological, biochemical/physiological or physical changes in the product. Factors identified as causes of deterioration usually encourage the conditions that lead to quality losses. These factors are usually the result of inadequate training of product handlers, inadequate or non-existent storage structures, unsuitable or inadequate technologies for handling and storing product, ineffective quality control, and adverse/extreme environmental conditions. In addition, time is an important factor in the spoilage of produce.

2.2 Learning Outcomes

By the end of this unit, you will be able to:

- Write the major sources of food deterioration
- Discuss the role of temperature, packaging and composition of food in food spoilage
- Explain the influence of initial microbial load and the nature and types of microorganisms present
- Discuss the extrinsic and intrinsic factors of food that affect deterioration
- Analyse other forms of deterioration arising from insect infestation and rodent attacks.

1.3 Causes of Deterioration and Spoilage

Foods are often classified on the basis of their stability as: non-perishable, semi-perishable and perishable.

1. **Non-perishable foods:** Hermetically sealed and heat processed (canned) foods are generally regarded as non-perishable. However, they may become perishable under certain circumstances when an opportunity for recontamination is afforded following processing. Such an opportunity may arise if the cans are faulty, or if there is excessive corrosion resulting in internal gas formation and eventual bursting of the can. Spoilage may also take place when the canned food is stored at unusually high temperatures: thermophilic spore-forming bacteria may multiply, causing undesirable changes such as flat sour spoilage.
2. **Semi-perishable foods:** Low moisture content foods such as dried fruit and vegetables are classified as semi-perishable. Frozen foods, though basically perishable, may be classified as semi-perishable provided that they are properly stored at freezer temperatures.
3. Perishable foods: The majority of foods such as meat and fish, milk, eggs and most fresh fruits and vegetables are classified as perishable unless they have been processed in some way.

1.3.1 Chemical factors

Deterioration may result from chemical reactions (via endogenous enzymes) or through interactions involving one or more of the macronutrients present in food and food products. Enzymes are proteins that occur naturally in plant tissues and catalyze a number of important biochemical reactions. Some enzyme-catalyzed reactions are beneficial while others result in quality deterioration. Examples of reactions involving endogenous enzymes include:

1. the post-harvest spoilage of fruit and vegetables
2. oxidation of phenolic substances in plant tissues by phenolase
3. sugar - starch conversion in plant tissues by amylases

4. post-harvest demethylation of pectic substances in plant tissues (leading to softening of plant tissues during ripening, and firming of plant tissues during processing).
5. development of off-flavours through the breakdown of lipid components; and loss of color and undesirable browning.
6. catalyze fermentation of sugars, breakdown of ascorbic acid, and many other deterioration reactions. Bruising, ripening, cutting, temperature, and presence of co-factors (sFe and Mg) increase the rate of degradative enzyme activity.

1.3.2 Physical Factors

One major undesirable physical change in food powders is the absorption of moisture as a consequence of an inadequate barrier provided by the package; this results in caking. It can occur either as a result of a poor selection of packaging material in the first place, or failure of the package integrity during storage. In general, moisture absorption is associated with increased cohesiveness.

Anti-caking agents are very fine powders of an inert chemical substance that are added to powders with much larger particle size in order to inhibit caking and improve flow-ability. At higher activities, however, (aw > 0.45) the observed time to caking is inversely proportional to water activity, and at these levels anti-caking agents are completely ineffective. It appears that while they reduce inter-particle attraction and interfere with the continuity of liquid bridges; they are unable to cover moisture sorption sites.

1.3.3 Biological Factors

1.3.3.1 Microorganism

The presence of pests and/or their droppings is a cause for alarm. Pests can spread disease-causing organisms to foods. Pests such as insects, rodents and birds are often identified as causes of biological deterioration of produce. They also cause damage to the surface of fruits and vegetables leading to greater susceptibility to invasion by microorganisms that can cause food spoilage and/or diseases to consumers. Proper sanitation in all produce handling and storage areas is the most effective weapon against these pests. Microorganisms can make both desirable and undesirable changes to the quality of foods depending on whether or not they are introduced as an essential part of the food preservation process or arise unintentionally and subsequently grow to produce food spoilage.

Bacteria and fungi (yeasts and moulds) are the two major groups of microorganisms found in foods. Bacteria are generally the fastest growing and outgrow fungi in conditions favourable to both. Spoilage microorganisms including bacteria, fungi, and viruses are major causes of food deterioration. These organisms may cause softening, off-colour, and off-flavour in foods. Disease causing microorganisms (pathogens) will result in illness of those consuming the food if present in sufficient quantity. Fruits and vegetables offer considerable resistance to microbial activity, however, the softening that usually accompanies aging of products and mechanical injuries increase the susceptibility of produce to microorganisms.

The species of microorganisms which cause the spoilage of particular foods are influenced by two factors:

1. The nature of the foods
2. Their surroundings/environment.

These factors are referred to as intrinsic and extrinsic parameters. The intrinsic parameters are an inherent part of the food and include pH, water activity, nutrient content, antimicrobial constituents and biological structures. The extrinsic parameters of foods are those properties of the storage environment that affect both the foods and their microorganisms. The growth rate of the microorganisms responsible for spoilage primarily depends on these extrinsic parameters: temperature, relative humidity and gas compositions of the surrounding atmosphere.

1.3.3.2 Insect Pests

Warm humid environments promote insect growth, although most insects will not breed if the temperature exceeds about 35 °C or falls below 10 °C. Also many insects cannot reproduce satisfactorily unless the moisture content of their food is greater 11%. The main categories of foods subject to pest attack are cereal grains and cereal-based products, other seeds used as food, dairy products such as cheese and milk powders, dried fruits, dried and smoked meats and nuts.

The presence of insects and insect excrete in packaged foods may render products unsaleable, causing considerable economic loss, as well as reduction in nutritional quality, production of off-flavours and acceleration of decay processes due to creation of higher temperatures and moisture levels. Early stages of infestation are often difficult to detect; however, infestation can generally be spotted not only by the presence of the insects themselves but also by the products of their activities such as webbing, clumping together of food particles and holes in packaging materials.

Unless plastic films are laminated with foil or paper, insects are able to penetrate most of them quite easily, the rate of penetration usually being directly related to film thickness. Thicker films are more resistant than thinner films, and oriented films tend to be more effective than cast films. The looseness of the film has also been reported to be an important factor, loose films being more easily penetrated than tightly fitted films. Generally, the penetration varies depending on the basic resin from which the film is made, on the combination of materials, on the package structure, and of the species and stage of insects involved. The relative resistance to insect penetration of some flexible packaging materials is as follows:

i. **Excellent resistance:** polycarbonate and poly-ethylene-terephthalate
ii. **Good resistance:** cellulose acetate, polyamide, polyethylene (0.254 mm), polypropylene (biaxially oriented) and poly-vinyl- chloride (unplasticised).
iii. **Fair resistance:** acrylonitrile; poly-tetra-fluoro-ethylene and polyethylene (0.123 mm).
iv. **Poor resistance:** regenerated cellulose, corrugated paper board, kraft paper, polyethylene (0.0254 - 0.100 mm), paper/foil/polyethylene laminate pouch and poly-vinylchloride (plasticized).

1.3.3.3 Rodents

Rodents carry pathogens on their feet and/or in their intestinal tracts and are known to harbour *Salmonella* of serotypes frequently associated with human food-borne infections. In addition to the public health consequences of rodent populations in close proximity to humans, they also compete intensively with humans for food.

Rodents gnaw to reach sources of food and drink and to keep their teeth short. Their incisor teeth are so strong that rodents have been known to gnaw through lead pipes and unhardened concrete, as well as sacks, wood and flexible packaging materials. Proper sanitation in food processing and storage areas is the most effective weapon in the fight against rodents, since all packaging materials apart from metal and glass containers can be attacked by rodents.

1.3.4 Effect of Deterioration on Food Quality

Chemical, physical and biological changes which occur during handling, processing and storage of foods lead to deterioration in sensory and nutritional quality of foods.

1.3.4.1 Sensory Quality

i. Lipid Oxidation

Lipid oxidation rate is influenced by light, local oxygen concentration, high temperature, the presence of catalysts (transition metals such as iron and copper) and water activity. Control of these factors can significantly reduce the extent of lipid oxidation in foods.

ii. Non-enzymatic browning

Non-enzymatic browning is one of the major causes of deterioration which occurs during storage of dried and concentrated foods. The non-enzymatic browning or Maillard reaction can be divided into three stages:

1. Early Maillard reactions which are chemically well-defined steps without browning.
2. Advanced Maillard reactions which lead to the formation of volatile or soluble substances
3. Final Maillard reactions leading to insoluble brown polymers.

iii. Colour changes

Chlorophylls: Almost any type of food processing or storage causes some deterioration of the chlorophyll pigments. Phenophytinisation is the major change and it is acid catalyzed reaction accelerated by heat. Dehydrated products such as green peas and beans packed in clear glass containers can undergo photo-oxidation and loss of desirable colour.

Anthocyanins: These are a group of more than 150 reddish water-soluble pigments that are very widespread in the plant kingdom. The rate of anthocyanin destruction is pH dependent, being greater at higher pH values. Of interest from a packaging point of view is the ability of some anthocyanins to form complexes with metals such as Al, Fe, Cu and Sn. These complexes result in an undesirable change in the colour of the pigment (red sour cherries react with tin to form a purple complex). Since metal packaging materials such as cans could be sources of these metals, they are usually coated with special organic linings to avoid these undesirable reactions.

Carotenoids: The carotenoids are a group of mainly lipid soluble compounds responsible for most of the yellow and red colours of plant and animal products. The main cause of carotenoid degradation in foods is oxidation. The pigments may auto-oxidize by reaction with atmospheric oxygen at rates dependent on light, heat and the presence of antioxidants.

iv. Flavour changes

Enzymatically generated compounds derived from long-chain fatty acids play an extremely important role in the formation of characteristic flavours. In addition, these types of reactions can lead to significant off-flavours. Enzyme-induced oxidative breakdown of unsaturated fatty acids occurs extensively in plant tissues and these yield characteristic aromas associated with some ripening fruits and disrupted tissues. The permeability of packaging materials is of importance in retaining desirable volatile components within packages, or in permitting undesirable components to permeate through the package from the ambient atmosphere.

1.3.4.2 Nutritional Quality

The four major factors that affect nutrient degradation to varying extents are light, oxygen concentration, temperature, and water activity. However, due to the diverse nature of the various nutrients, chemical heterogeneity within each class of compounds and complex interactions of the above variables, generalizations about nutrient degradation in foods will inevitably be broad ones.

Ascorbic acid (Vitamin C) is the most sensitive vitamin in foods and its stability vary markedly as a function of environmental conditions such as pH and the concentration of trace metal ions and oxygen. The nature of the packaging material can significantly affect the stability of ascorbic acid in foods. The effectiveness of the material as a barrier to moisture and oxygen as well as the chemical nature of the surface exposed to the food are important factors. For example, problems of ascorbic acid instability in aseptically packaged fruit juices have been encountered because of oxygen permeability of the package and the oxygen dependence of the ascorbic acid degradation reaction. Also, because of the preferential oxidation of metallic tin, citrus juices packaged in cans with a tin contact surface exhibit greater stability of ascorbic acid than those in enamelled cans or glass containers. The aerobic and anaerobic degradation reactions of ascorbic acid in reduced moisture foods have been shown to be highly sensitive to water activity, the reaction rate increasing in an exponential fashion over the water activity range of 0.1-0.8.

Self- Assessment Exercises 1

1. What are the four major factors that affect nutrient degradation?
2. What are the two factors that influence the species of microorganisms which cause the spoilage of particular food?

1.4 Contamination and spoilage of foods

1.4.1 Spoilage of cereals and cereal products

Cereals are important foods which provide bulk of our dietary requirements. They are also source of carbohydrates which are metabolized by body for energy generation. Besides, cereals also provide minerals, proteins and vitamins. Nigeria produces a large variety of cereals such wheat, maize, barley, millets, etc. Various types of products are prepared from cereals.

Cereal products can be broadly classified into the following groups:

- Whole cereals where only the husk of the grain is removed such as rice, wheat, gram, lentils, etc.
- Milled grain products are made by removing the bran and usually the germ of the seed and then crushing the kernel into various sized pieces to produce wheat flour, maida, semolina, etc.
- Processed cereals like weaning food, breakfast cereals, etc.
- Ready mixes like cake mix, idli mix, vada mix etc.

India is self-sufficient in grain production and is the second largest rice producer in the world with a 20% share. But due to constantly increasing population there is still a shortfall in cereals. A large amount of these cereals is spoilt every year due to various factors.

Spoilage Factors

The grains are low moisture commodities and are less susceptible to spoilage, hence, have greater shelf life. The spoilage mainly occurs due to moisture absorption during storage leading to fungal growth at high temperature and humidity. Before bulk packaging and storage, the whole grains are usually fumigated to reduce microbial load and increase storage period. The three factors influencing the quality of cereals are:

Physical factors

Physical losses are caused by spillages occurring due to use of faulty packaging materials.

Physiological

Physiological losses occur as a result of respiration and heating in grains, temperature, humidity and oxygen.

Biological factors

Biological losses occur due to microorganisms, insects, rodents, and fungi.

The sources of contamination in cereals are:

- Soil
- Air
- Insects
- Natural microflora of harvested grains

1.4.1.1 Cereal Grains and Flours

At initial stages, the grains are contaminated by *Pseudomonas*, *Micrococci*, *Lactobacillus* and *Bacillus*. The initial bacterial and mould population varies from one grain to another. Due to low moisture content, grains and flours usually have long shelf life if properly harvested or stored under proper conditions. Spoilage of stored grains by molds is attributed to the following factors:

1. Type and number of microorganisms
2. Moisture content of more than 12-13%
3. Storage temperature
4. Physical damage

Most common species of molds are *Aspergillus, Rhizopus, Mucor and Fusarium*. A significant aspect of spoilage of molds is production of mycotoxins which may pose danger to health.
The process of flour making such as washing and milling reduces the microbial load of product. Moisture content of less than 15% does not allow growth of molds. Most molds and bacteria in flours can grow only above 17% moisture, thus moistening of flours is essential for spoilage by microorganisms.

Spoilage of Bread

Bread is prepared from flours which undergo fermentation for which desirable microorganisms must grow. If this fermentation exceeds the required limits, it causes souring. Excessive growth of proteolytic bacteria reduces the gas holding capacity which is otherwise required for dough rising. Spoilage of bread is usually of two types namely: moldiness and ropiness. During bread making, it is baked at very high temperature thereby leaving less chances of survival of microorganisms. Thus, the contamination usually occurs when cooling is done as well as during packing, handling and from the environment. The molds which are prevalent are *Rhizopus stolonifer* (referred as bread mold), *Penicillium expansum, Aspergillus niger*. Mucor and Geotrichum also develop.

The ropiness in bread is usually due to bacterial growth and is considered more prevalent in homemade breads. The main causative organism is *Bacillus subtilis* or *B. licheniformis*. These are spore forming bacteria with their spores surviving baking temperatures. These spores can germinate into vegetative cells, once they get suitable conditions as heat treatment activates them. In ropiness, the hydrolysis of bread flour protein takes place by proteinases. Starch is hydrolysis by amylases encourages ropiness. The manifestation of ropiness is development of yellow to brown color and soft and sticky surface accompanied by odor.

Another type of spoilage of bread is chalky bread which is caused by growth of yeast like *Endomycosis fibuligera* and *Trichosporon* variable and characterized by development of white chalk like spots.
An unusual spoilage of bread is Red or Bloody bread, which is due to the growth of the bacteria *Serratia marcescens*. This organism produces brilliant red color on starchy foods giving blood like appearance. *Neurospora* and *Geotrichum* may also be involved in imparting pigmentation during spoilage of bread.

1.4.2 Contamination and Spoilage of Vegetables

Vegetables form an integral part of diet due to their role in providing various types of vital nutrients such as carbohydrates, minerals, vitamins, roughages etc. Vegetables being a part of fresh produce, contain high moisture which makes them highly perishable foods and hence more prone to spoilage. Microorganisms gain entry into vegetables from various sources including:

1. Soil
2. Water
3. Diseased plant
4. Harvesting and processing equipment
5. Handlers
6. Packaging and packing material
7. Contact with spoiled vegetables

The conditions in which vegetables are stored and transported after harvesting also contribute to rate of spoilage.

Types of Spoilage in Vegetables

The microbial spoilage of vegetables is predominately of following types

i. Spoilage due to pathogens

The plant pathogens which infect stems, leaves, roots, flowers, fruits, and other parts of the plant causing different plant diseases.

ii. Spoilage due to saprophytes

Vegetables have general microflora inhabiting them which grows under certain conditions and spoil them. There are certain secondary invaders which may enter the healthy food or grow after growth of pathogens. It is well known that plant diseases are mostly caused by fungi. Thus, most of the spoilage causing pathogens in vegetables is fungi. Fungi have specific characteristics when spoiling food as it leads to mushy areas which may be water soaked. The fungi produce characteristic spores which may be pigmented. The pigmentation helps in identification of the type of spoilage by fungi. The bacterial diseases too cause spoilage of vegetables but to a lesser extent.

Spoilage in vegetables is largely affected by composition of vegetable. The non-acidic foods are spoiled by bacterial rot while acidic foods with dry surfaces are more prone to mold spoilage. The product on which organism grows and types of organisms growing largely determine the character of spoilage.

Bacterial Soft Rot

i. Caused by *Erwinia carotovora* and *Pseudomonas* such as *P. marginalis*. *Bacillus* and *Clostridium species* are also implicated.

ii. Breaks down pectin, giving rise to a soft, mushy consistency, sometimes a bad odour and water-soaked appearance.

iii. Vegetables affected include onions, garlic, beans, carrot, beets, lettuce, spinach, potatoes, cabbage, cauliflower, radishes, tomatoes, cucumbers and watermelons.

Fungal spoilage of vegetables

Penicillium, Cladosporium, Rhizopus and *Aspergillus species* are responsible for various defects in vegetables. Gray mold rot caused by *Botrytis cinera* in vegetables is favoured by high humidity and warm temperature

1.4.3 Contamination and Spoilage of Fruits

Fruits are natural sources of minerals, vitamins besides carbohydrates and other essential substances. Naturally fresh fruits and juices made out of them contain high amount of water thereby making them highly prone to attack by microorganisms. Most of the fruits are naturally provided with coatings and coverings in the form of skins but these are fragile enough to be easily disturbed by various biological and mechanical factors. Like vegetables, fruits being foods of plant origin get contaminated through different sources by a variety of microorganisms which may play significant role in their spoilage. These are soil, water, diseased plant, harvesting and processing equipment, handlers, packaging and packing material and contact with spoiled fruits.

Microorganisms associated with spoilage in fruits and juices

The microorganisms associated with fruits depend on the structure of fruit. The fruits contain different organic acids in varying amounts and the predominately found of acids are citric acid, malic acid and tartaric acid. The low pH of fruits restricts the proliferation of various types of organisms.

Due to the low pH, a large number of microorganisms are restricted to grow on fruits. Fungi are most dominating organisms to grow on fruits because of the ability of yeasts and molds to grow under acidic conditions. A small number of bacteria which are aciduric grow on fruits. The dry conditions prevailing on the skin and surface do not allow the growth of certain microorganisms and these plants also produce certain antimicrobial components too. Despite the high water activity of most fruits, the low pH leads to their spoilage being dominated by fungi, both yeasts and molds.

a. Yeasts

Yeasts are unicellular fungi which normally reproduce by budding. Of the 215 species important in foods, about 32 genera are associated with fruits and fruit products. Only a few species of yeasts are pathogenic for man and other animals but none of the pathogenic species are common contaminants of fruits and fruit products. Fruit that has been damaged by birds, insects, or pathogenic fungi usually contain very high yeast populations. The yeasts are introduced into the exposed tissue, often by insects, and are able to use the sugars and other nutrients to support their growth. Types of yeasts growing in fruits depend upon the nature of the fruit and the strain of yeast. Growth of a strongly fermentative type such as certain strains of *Saccharomyces cerevisiae* may produce sufficient CO_2 to burst the container. Growth of some species in a clear fruit juice may produce only slight haze and sediment. Carbon dioxide and ethanol are the predominant metabolic products of yeasts but other products such as glycerol, acetaldehyde, pyruvic acid, and a - ketoglutaric acid are also formed. Oxidative yeasts such as species of *Brettanomyces* produce acetic acid in wines and other fruit products. Although yeasts produce hydrolytic enzymes which degrade pectins, starch, and certain proteins, enzymatic activity is usually much less than that exhibited by other aciduric microorganisms (molds in particular).

b. Moulds

c.

Moulds are filamentous fungi which are important group of microflora of fruits and fruit products. Some of the members are xerophilic, thereby having potential to spoil foods of low water activity such as dried fruits and fruit juice concentrates. Some of the species have heat resistant spores such as ascospores which can survive the commercial pasteurization treatments that are given to most fruit products. Growth of molds on processing equipment such as wooden tanks can result in the generation of off-flavors in wines, juices, and other fruit products. Mold-infected raw fruit may become soft after processing because pectinases will not inactivated by the thermal treatment. The metabolic products of many molds are toxic to humans, e.g. mycotoxins.

Moulds are aerobic microorganisms, but many of them are very efficient scavengers of oxygen. Due to this property of molds, processed fruits, including those hermetically sealed in cans or glass, are susceptible to spoilage. In case of limited vegetative growth, evidence of spoilage may be the changes produced by fungal enzymes such as the breakdown of starch or pectins while in case of heavy growth, colonies develop in the headspace or as strands throughout a beverage or similar product.

Some types of spoilage by fungi

Rhizopus stolonifer cause soft and mushy food, cottony growth of mold.

Anthracnose

Colletotrichum lindemuthianum, cause spotting of leaves and fruits and seed pods

Downy mildew:

Initially, the lesions tend to be small and confined to the upper surface of wrapper leaves. As the areas enlarge, they turn from light green or yellowish to brown and become soft. It is caused by *Phytophthora*.

Watery soft rot

This rot occurs on the lower part of water soaked and light or pinkish brown called leads. A white cottony mold spreads over the decayed tissue and the lead eventually becomes a watery mall.

d. Bacteria:

Various groups of bacteria have ability to grow on fruits and its juices. These bacteria by virtue of their diversity in metabolism grow on fruits and produce different types of compounds. The major groups of bacteria of bacteria that grow on the fruits:

- Lactic acid bacteria
- Acetic acid bacteria
- Spore forming bacteria

Lactic acid bacteria

The lactic acid bacteria are Gram-positive, catalase negative, rod-shaped (lactobacilli), or cocci organisms which can grow under anaerobic conditions. The homo fermentative species produce mainly lactic acid from hexose sugars; the hetero fermenters produce one molecule of lactic acid, one molecule of carbon dioxide, and a two-carbon compound, which is usually acetic acid or ethanol or a combination of the two.

Growth of lactic acid bacteria in juices and other fruit products cause the formation of haze, gas, acid, and a number of other changes. Certain hetero-fermentative *lactobacilli* lead to slime in cider. The *lactobacilli* and *leuconostocs* that are present in citrus juices generate acetylmethylcarbinol and diacetyl, compounds that give the juices an undesirable, butter-milk-like flavor. Lactic acid bacteria have the ability to decarboxylate malic acid to lactic acid. This malo-lactic fermentation is often desirable in high-acid wines because the acidity is reduced and desirable flavors are produced. *Oenococcus oenos* is the most acid and alcohol-tolerant species often isolated from wines that are undergoing a malo-lactic fermentation.

Acetic acid bacteria

These are Gram negative, aerobic rods having two genera, namely: *Acetobacter* and *Gluconobacter*. These species oxidize ethanol to acetic acid under acidic condition, *Acetobacter* species can oxidize acetic acid to carbon dioxide thus, the genus is called over oxidizer. The bacteria are obligate aerobes, so, juices, wines, and cider are most susceptible to spoilage while held in tanks prior to bottling. Some strains of *Acetobacter pasteurianus* and *Gluconobacter oxydans* produce microfibrils composed of cellulose, which leads to formation of flocs in different fruit juice beverages.

Spore forming bacteria

Spores are heat resistant, so, the role of organisms producing spores is important in heat treated of juices and beverages. Various spore formers such as *Bacillus coagulans, B. subtilis, B. macerans, B. pumilis, B. sphaericus* , and *B. pantothenticus* have been found to grow in different types of wines. Some of these organisms have also been involved in canned fruits. Sporeforming *bacilli* that actually prefer a low pH have been responsible for spoilage of apple juice and a blend of fruit juices.

1.4.4 Contamination and Spoilage of Meat and Meat Products

The microbiological profile of meat products presented to the consumers is the sum total of the slaughtered animal health, conditions under which it was reared, quality of slaughtering, processing, packaging and conditions under which the meat was stored. Meat pathogens can cause self-limiting human enteric diseases or systemic and fatal infections of the immunocompromised, the elderly and the young. Meat can act as an ideal substrate for microbial proliferation. Major meat associated pathogenic bacteria include *Clostridium perfringens, Staphylococcus aureus, Salmonella spp, pathogenic strains of Escherichia coli, Campylobacter spp, Yersinia enterocolitica*, *Listeria monocytogenes and Aeromonas hydrophila*.

Microorganisms Associated With Meat during Processing

Meat spoilages indicate:

i. Color changes
ii. Textural changes
iii. Development of off-flavour or off-odor or slime as a result of microbial growth.

Salmonella is the primary microbial challenge of poultry *and Escherichia coli* O157: H7 is the primary microbial to the beef industry. *Listeria*, which is an adulterant with zero tolerance, is the major problem for ready to eat meat products. Treatment with organic acids, hot water steam, carcass pasteurization and steam carcass vacuuming, trisodium phosphate, acidified sodium chlorite, chlorine dioxide, lactoferrins, peroxyacetic acid, sodium lactate, sodium acetate and sodium diacetate, ozone and radiation have been used as microbial decontaminants during meat processing operations. Carcass washing with hot water of 80°C for 10 seconds can reduce microbial loads by two logs. Current regulatory policies and inspection in the meat industry include the HACCP (Hazard Analysis Critical Control Point) food safety system with an objective to provide safe food for consumption and prevent chemical, physical and biological hazards.

Gram-negative bacteria (Aerobes): *Neisseriaceae: Psychrobacter immobilis, P. phenylpyruvica, Acinetobacter spp., A. twoffii, A. Johnsonii, Pseudomonadaceae: Pseudomonas fluorescens, P. lundensis, P. fragi*, and *P. putida*

Gram-positive bacteria: *Brochothrix thermosphacta, Kurthia zophii, Staphylococcus spp., Clostridium estertheticum, Clostridium frigidicarnis, Clostridium casigenes,* and *Clostridium* sp.

Meat Spoilage

Meats are composed mainly of protein and fats rather than carbohydrates. Water content is 71–76% and therefore moisture is not an issue except for spoilage microbes on cured meats. Muscles of healthy animals do not contain any bacteria or fungi but as soon as animals are slaughtered, meat is exposed to contaminants and good sanitation practices are essential to produce high quality meats. The number of spoilage organisms on meat just after slaughter is a critical factor in determining its shelf life. The surface of beef carcasses may contain anywhere from 101 to 107 cfu/cm2, most of which are psychrotrophic bacteria.

Chopping and grinding of meats can increase the microbial load as more surface area is exposed and more water and nutrients become available for microbial growth. A large variety of microbes are commonly found on fresh meat, but different microbes become dominant during spoilage of different meats depending on pH, composition and texture of processed meats, temperature and packaging atmosphere. *Pseudomonas spp*. is the predominant spoilage bacteria in aerobically stored raw meat and poultry. Once the initial low levels of glucose are depleted by various microbes, *Pseudomonas* has an advantage because it can catabolize gluconates and amino acids more readily than other microbes. Break down of these compounds results in production of malodorous sulfides, ammonia, and amines, including the biogenic amines, putrescine and cadaverine. Dark, firm and dry meat with a relatively high pH of 6.0 spoils more rapidly because deamination of amino acids starts earlier. *Shewanella putrefaciens* does not grow on meat at pH<6.0 but can produce sulfides and ammonia even when glucose is still available. These sulfides not only smell bad but also cause color changes in meat, and therefore *Shewanella* has a high spoilage potential on fresh, high pH meats stored aerobically even when it is not a dominant microbe. *Brochothrix thermosphacta* is often a significant spoilage organism on fresh meat stored aerobically at refrigeration temperatures. Enterobacteriaceae, particularly species of *Serratia*, *Enterobacter*, and *Hafnia*, are major causes of spoilage in vacuum-packed, high pH fresh meats. These organisms are facultative anaerobes that produce organic acids, hydrogen sulfide and greening of meats.

Lactic acid bacteria (LAB) grow on meat and poultry packaged under vacuum and modified atmospheres, producing organic acids from glucose by fermentation. This gives rise to aciduric off-odors which may be accompanied by gas and slime formation and greening of meat. However, LAB is weakly proteolytic and so do not produce large amounts of amines or sulfides, and spoilage of meat by LAB is not as offensive. Psychrophilic, anaerobic *Clostridium species* are associated with spoilage of vacuum-packaged meats. "Blown pack" meat spoilage is characterized by excessive gas formation with off-odours due to formation of butyric acid, butanol, and sulfurous compounds. Yeasts and molds grow relatively slowly on fresh meat and do not compete well with bacteria; hence, they are a minor component of spoilage flora.

Spoilage of Processed Meat

Addition of sodium chloride, nitrites and/or nitrates, along with various other seasonings, emulsifiers, and preservatives to ground or whole muscle meats changes the environment significantly and also the spoilage flora of processed meats. Dried and dry-fermented meats generally do not support microbial growth although process deviations may allow growth of some organisms. Spoilage organisms can grow on fresh and cooked cured meats, so they are best stored chilled, under a vacuum or modified atmosphere. *Pseudomonas* spp. are not usually important causes of spoilage in processed meats because of their sensitivity to curing salts and heat pasteurization and their inability to grow well in meats packed with a vacuum or high carbon dioxide atmosphere. But these bacteria may spoil refrigerated processed meats when packages have been opened and there has been insufficient curing. Some cold and salt tolerant Enterobacteriaceae have been found to cause spoilage in some specific processed meats, such as ham or bacon.

Lactic acid bacteria (LAB) are the group of bacteria primarily associated with spoilage of processed meats. They produce sour off-flavors, gas, slime, and greening, and this spoilage may be more severe than in fresh meat because of the presence of added carbohydrates. Competitive ability of different LAB strains is related to pH and water activity of the meat, cooking and storage temperatures and oxygen and carbon dioxide levels. Spore formers (*Clostridium* and *Bacillus spp.*) are usually not a spoilage problem in processed meats because of the presence of nitrite and other curing salts. But faulty cooking/cooling procedures, including long cooling periods and temperature abuse, has allowed the growth of these organisms in some cases. Spores of these organisms may be introduced with spices or other ingredients. Yeasts cause some spoilage in processed meats but are generally only important when sulfite is used as a preservative or when meats have been irradiated or stored aerobically in the cold. In some sausages, slime may be produced along with vinegary or malty off-odours.

1.4.5 Contamination and Spoilage of Milk and Milk Products

Milk secreted from an uninfected animal’s udder is sterile. It becomes contaminated during milking, cooling and/or storage. It is an excellent medium for the growth of bacteria, yeasts and moulds that are the common contaminants of any food material. Their rapid growth, particularly at high ambient temperatures can spoil the milk for liquid consumption and for manufacturing dairy products.

Spoilage of milk

As a result of microbial growth or biochemical activities, cause undesirable changes in milk and, are responsible for spoilage. Milk producer should be aware of the sources of microorganisms causing rapid changes, conditions favoring their growth, and methods of preventing their activity. The manufacturer of milk products must contend with problems similar to those of producer of milk and additional ones also, as milk products (butter, cheeses, etc.) are frequently stored for longer periods, during which there may be further decrease quality. The problem of spoilage is especially important with the cheeses. They require ripening, since conditions must be favorable for growth of certain desirable microorganisms and may also allow the growth and development of undesirable ones.

The initial microbial quality of raw milk is quite crucial for the production of good quality dairy foods. Spoilage is a term used to describe the deterioration of a foods texture, color, odor or flavour to the point, where it becomes unsuitable for human consumption. Microbial spoilage of food often involves the degradation of protein, carbohydrates, and fats by the microorganisms or their enzymes. The microorganisms that are mainly involved in spoilage of milk are psychrotrophs and are destroyed by pasteurization; however, some like *Pseudomonas fluorescens and Pseudomonas fragican* produce proteolytic and lipolytic extracellular enzymes that are heat stable and capable of causing spoilage. Some species and strains of *Bacillus, Clostridium, Corynebacterium, Arthrobacter, Lactobacillus, Microbacterium, Micrococcus,* and *Streptococcus* can survive pasteurization and grow at refrigeration temperatures that can cause spoilage problems in milk and milk products.

Sources of Microbial Contamination of Milk

Microbial contamination of milk can be from the internal and/ or external sources as described below.

Interior of udder

Varying numbers of bacteria are found in aseptically drawn milk with the reported counts of <100-10,000 CFU/ml from normal udder, but an anticipated average is 500-1000 CFU/ml in advanced countries. Microorganisms enter the udder through the duct at the teat tip that varies in length (from 5-14 mm) and its surface is heavily keratinized. This keratin layer retains the milk residues and exhibit antimicrobial activity.

During progress of a milking, bacteria are present in the largest numbers at the beginning and then gradually decrease. This is mainly due to the mechanical dislodging of bacteria, particularly in teat canal, where the numbers are probably highest. Because of this, discarding of first few streams of milk helps in lowering the counts of microbes in milk.

Micrococci are slow growing, mostly non-pathogenic but if allowed to grow, they cause acid formation and proteolysis. Streptococcus agalactiae may be present even in non-clinical mastitis and thus it appears to be a natural inhabitant of udder. *Corynebacterium bovis,* a Gram positive rod has been found in large numbers. It is non-pathogenic, but if grown causes rancidity. If an animal is infected from mastitis, microbial contamination from within the udder of animal contributes notably to the total numbers of microbes in the bulk milk, when compared with the milk originated from a healthy animal. The influence of mastitis on the total bacterial count of milk depends on the type of the infecting microbe. Most common microbial agents of mastitis in milch animals are *Staphylococcus aureus, Streptococcus agalactiae, Streptococcus dysgalactiae, Streptococcus uberis, Escherichia coli,* and *Corynebacterium pyogenes.*

Exterior of udder

In addition, to the udder infections, unclean udder and teats of animal also contribute significantly to the total bacterial counts of milk. The microbes that are naturally associated with the skin of the animals as well as those derived from the environment, where the cow is housed and milked are predominant in the milk. The environmental conditions such as soil, manure, mud, feed or bedding; determines what kind of microbes will dominate in milk. Udder and teat become soiled with dung, mud, bedding material such as saw dust and straw. With heavily soiled udder teats the counts may be up to100,000 cfu/ml. The bedding material in winter has high number of bacteria, mainly psychrotrophs, coliforms and *Bacillus spp*. Udder microflora is not affected much by simple washing but economy washing with sodium hypochlorite accompanied by drying, helps in reducing the number of microbes. Categories of microbes that occurs in the exterior of udder are:

1. Predominantly *Micrococci* and coagulase negative *Staphylococci* exist.
2. Next, on the teat surface are faecal *Streptococci*, but gram-negative bacteria including coliforms are less. Coliforms do not survive well on teat surface.
3. Aerobic thermoduric organisms are entirely *Bacillus spp*. The more frequent are *B. licheniformis, B. subtilis, B. pumilis* and less frequent ones are *B. cereus, B. circulans* and *B. firmus*.
4. Teat surface may also contain *Clostridia* spores that are usually found in cows' fodder, bedding and feces.

   Psychrotrophic and thermoduric bacteria predominate on the teat surfaces. The psychrotrophs that can grow at 7^{o}C and below are mostly Gram negative rods, and the major ones are *Pseudomonas fluorescens, Alcaligenes* and *Flavobacterium*. On the other hand, thermodurics on teat surfaces are often bacterial spores (a dormant and nonreproductive structure; highly resistant to radiations, desiccation, lysozymes, high temperature, starvation and disinfectants) that are typically found in the soil. When these spores enter the bulk milk, they may survive during pasteurization and cause a number of post-pasteurization problems.

Coat of cow

The coat serves as a vehicle to contribute bacteria directly to milk. The hairs around udder, flanks and tail contribute to the higher bacterial count in milk. The coat may indirectly contribute microbes into air, especially *Bacillus spp*. The coat may carry bacteria from the stagnant water pools, especially ropiness causing milk microbes.

Animal shed and surroundings

Milk produced on farms with poor hygiene practices may undergo significant spoilage and have a shorter shelf-life compared to milk produced under hygienic conditions.

Microbes associated with the bedding materials include:

i. Coliforms
ii. Spore-formers
iii. Staphylococci
iv. Streptococci
v. Other Gram negative bacteria

Milking staff

Soiled clothes and hands increase the risk of contamination of milk and milking equipment many folds. Milker with infected wounds on hands contributes pathogenic *Streptococcus spp*. and *micrococci*. If wet hand milking is practiced, the microorganisms present in lubricants like fore-milk, water or saliva of the milker and bacteria from hands and teats will enter the milk.

The common microbial pathogens from humans causing diseases such as typhoid, paratyphoid and dysentery may contaminate the milk. Microbial pathogens causing scarlet fever, septic sore throat, diptheria, cholera etc. also contaminate the milk.

Milking equipment (storage containers and transportation systems)

Improperly cleaned milking and cooling equipment are one of the main sources of milk contamination. Milk residues left on the equipment contact surfaces supports the growth of a variety of microbes. The tanker and collecting pipes are also the potential sources of contamination, if not adequately cleaned. In addition, biofilms can easily build up on the enclosed, hard to clean surfaces.

Unclean or improperly cleaned milk cans and lids if they are still moist, results in multiplication of thermophilic bacteria like *Bacillus cereus*.

Improperly sterilized milking machines contain thermoduric *Micrococci*, *Bacillus* spp. and *Microbacterium spp*. compared to coliforms and *Streptococci*. Rubber hoses predominantly contribute to *Pseudomonads* rather than thermodurics.

Water supplies

At dairy farms, the water can be a predominant source of microbial contamination. Water used in production should be of good bacteriological quality. Inadequately or uncleaned, storage tanks, untreated water supplies from natural sources like bore wells, tanks and rivers, may also be contaminated with the fecal microbes (*Coliforms*, *Streptococci* and *Clostridia*). In addition, a wide variety of saprophytic bacteria (*Pseudomonas*, *Coliforms*, other Gram negative rods, *Bacillus* spores, *Coryneform* bacteria and lactic acid bacteria) may also be present in water and may contaminate the milk potentially. The warm water used for udder washing is potent source of *Pseudomonas* and *Coliforms* which may even cause mastitis.

Airborne contamination

Air contains dust, moisture and bacteria; hence its entry should be minimized in milk. *Micrococci, Coryneforms, Bacillus* spores, *Streptococci*, and Gram negative rods are the major genera present in air. The more air is incorporated into milk the faster the bacterial growth.

Colour changes in milk

i. Affected by amount and yellowness of butter fat, thinness of milk, content of blood and pus and feed of animal.
ii. Blue milk - *Pseudomonas syncyanea, Streptococcus lactis, Actinomycetes* or *Geotrichum* mold.
iii. Yellow milk - *Pseudomonas synxantha, Flavobacterium.*
iv. Red milk - *Serratia marcescens, Brevibacterium erythrogenes, Micrococcus roseus.*
v. Brown milk - *Pseudomonas putrefaciens, P.fluorescens*.

Spoilage of Butter

The cream quality and the sanitary conditions used in the butter processing are the major determinants of microbiological quality of butter.

All three major groups of organisms - bacteria (e.g., *Pseudomonas* spp.), yeasts (e.g., *Candida* spp.), and molds (e.g., *Geotrichum*) have been implicated in spoilage of butter on the surface causing flavour defects such as putridity, rancidity and/or fishy flavour as well as surface discoloration.

The flavor defects in unsalted butter have been attributed to growth of coliforms, *Enterococcus* and *Pseudomonas* in water-phase of butter.
Microorganisms of concern in the spoilage of butter are mainly psychrotrophs, which are predominantly Gram-negative, rod shaped microorganisms. The main characteristic of psychrotrophs which makes them important in the spoilage of butter, is their ability to survive at low temperatures (3–7ºC) and the production of enzymes (lipase and protease) which catalyze the hydrolysis of lipids and proteins in the butter, respectively.

The rich nutrient content of the butter also makes it susceptible to spoilage microorganisms other than *Pseudomonas* such as *Serratia*, *Acinetobacter* and *Moraxella*. Two main types of butter spoilage are color change at the surface (surface taint) and rancidity.

The major culprit for both is believed to be *Pseudomonas spp. Shewanella putrefaciens* (formerly *Alteromonas putrefaciens*) or *Flavobacterium spp*. which also play role in development of surface taints in butter. Some species such as *P. putrefaciens* are able to grow on butter surface and produce a putrid odour within a relatively short period of time (7–10 days) at refrigeration temperature. The odour is suggested to be the result of releasing organic acids such as isovaleric acid. Black discoloration and shunk-like odour are also developed in butter by *Pseudomonas nigrificans* and *Pseudomonas mephitica* respectively.
Pseudomonas fragi and, in rare cases, *Pseudomonas fluorescens* as well as non-microbial lipases degrade milk fat into free fatty acids leading to hydrolytic rancidity in butter.
Hydrolytic rancidity in butter can also be the result of activity of *Micrococcus spp*. and molds such as *Rhizopus, Geotrichum, Penicillium* and *Cladosporium.*

1.4.6 Contamination and Spoilage of Poultry

Poultry is susceptible to contamination by various sources. Contamination of skin and lining of the body cavity take place during various processing operations. The organisms of great importance in poultry are *Salmonella spp.* and *Campylobacter jejuni*. Several Gram negative psychrotropic bacteria such as *Pseudomonas*, *Acenitobacter* and *Flavobacterium* have also been isolated from poultry carasses. Ground turkey also may carry fecal *Streptococci*. It is important to freeze the poultry fast in order to keep it in good condition for several months. Freezing further reduces the number of microorganisms in the poultry meat provided the temperature is maintained quite low (-18 ° C or below).

The primary causes of poultry products spoilage are:

i. Prolonged distribution or storage time.
ii. Inappropriate storage temperature
iii. High initial bacterial counts
iv. High post-rigor meat pH

Spoilage factors

Companies are able to prevent prolonged storage times by properly rotating their stock. Product that is to be sold in locations far from the processing plant should be transported at temperatures that are below freezing point (26ºF), but not sufficient to freeze the muscle tissue.

Inappropriate storage temperatures or fluctuations in storage temperature are the most avoidable causes of spoilage. Temperature abuse can occur during distribution, storage, retail display or handling of the product by the consumer. Processors can determine whether product has been temperature abused by monitoring temperature or evaluating bacterial populations throughout the distribution system.

Initial bacterial counts on broiler carcasses may have a direct effect on the shelf-life of fresh product as well. The initial number of bacteria on poultry is generally a function of grow-out procedures, production practices, and plant and processing sanitation. Higher numbers of spoilage bacteria on the chicken immediately after processing, translates to more rapid spoilage. High post-rigor meat pH is often caused by stress on the birds during grow-out or transportation. This reduces the shelf-life of the meat by up to six days and is due to the fact that spoilage bacteria multiply much more rapidly on meat that is at a pH of 6.2 than on meat that is at a normal post-rigor pH of 5.4-5.6.

Bacteria responsible for spoilage

Research demonstrates that the populations of bacteria high in number on the carcass immediately after processing are not the ones that grow under refrigeration and spoil carcasses. The bacteria found after carcasses spoil are very difficult to find on carcasses at the time of processing. After processing, the spoilage bacteria are present in very low numbers, but they can multiply rapidly to cause spoilage odours and slime.

These spoilage bacteria are called psychrotrophic bacteria because they are able to multiply under cold conditions. Fresh poultry products held long enough at refrigerator temperatures will spoil as a result of the growth of psychrotrophic bacteria. In contrast, the bacteria that exist in higher numbers at the time of processing on the skin of chickens and in their intestinal tracts are primarily mesophiles. These bacteria do not multiply to an appreciable degree at refrigerator temperatures. *Salmonella, E. coli* and other bacteria found on chickens are mesophiles. When a company conducts an “Aerobic Plate Count” or “Total Plate Count” on a chicken carcass, it is measuring the mesophiles.

Origin of spoilage bacteria

Spoilage bacteria on the carcass immediately after processing come from the feathers and feet of the live bird, the water supply in the processing plant, the chill tanks and processing equipment. These spoilage bacteria are not usually found in the intestines of the live bird. High populations of *Acinetobacter* (108cfu/g) have been found on the feathers of the bird and may originate from the deep litter. Other spoilage bacteria, such as *Cytophaga* and *Flavobacterium*, are often found in chill tanks but are rarely found on carcasses.

The psychrotrophic spoilage bacteria on chicken carcasses immediately after slaughter are generally *Acinetobacter* and pigmented *pseudomonads*. Although strains of nonpigmented *Pseudomonas* produce off-odours and off-flavors on spoiled poultry, initially, they are difficult to find on carcasses *and P. putrefaciens* (*Shewanella putrefaciens*) is rarely found.

Spoilage species

The bacterial genera most isolated in high numbers on spoiled poultry were *Pseudomonas fluorescens*, *putida*, or *fragi* or *Shewanella putrefaciens*. Identification of the genus and species most responsible for spoiling poultry is important because, once identified, it is easier to understand the mechanisms by which they produce spoilage. High numbers (105 cfu/cm^2) of psychrotrophic spoilage bacteria are required on poultry surfaces before off-flavors, off-odors and appearance defects are able to be detected organoleptically. Researchers have reported that higher numbers of bacteria ($3.2x10^7$ to $1x10^9$ cfu/cm^2) were required to produce slime than were needed for odor to become noticeable.

Causes of spoilage defects

Spoilage is caused by the accumulation of metabolic by-products or the action of extracellular enzymes produced by psychrotrophic spoilage bacteria as they multiply on poultry surfaces at refrigeration temperatures. Some of these by-products become detectable as off-odours and slime, as bacteria utilize nutrients on the surface of meats.

Off-odours do not result from breakdown of the protein in skin and muscle, as previously thought, but from the direct microbial utilization of low molecular weight nitrogenous compounds such as amino acids, which are present in skin and muscle. Concentrations of free amino acids increase as proteolysis occurs throughout the storage period. It has been demonstrated that measurement of these free amino acids, due to the production of aminopeptidases and subsequent breakdown of protein, may be used to rapidly determine the bacteriological quality of beef.

Development of off-odours and slime

Microorganisms appear first in damp pockets on the carcass, such as folds between the foreleg and breast of a carcass, and their dispersion is promoted by condensation which occurs when a cold carcass is exposed to warm, damp air.

An ester-like odor, which was described as a "dirty dishrag" odour, can develop on cut-up chickens. Off-odour precedes slime formation and is considered the initial sign of spoilage in most cases. Immediately after off-odours are detected, many small, translucent, moist colonies may appear on the cut surfaces and skin of the carcass. Eventually, meat surfaces become coated with tiny drop-like colonies, which increase in size and coalesce to form a slimy coating.

In the final stages of spoilage, the meat may begin to exhibit a pungent ammoniacal odour in addition to the dirty dishrag odour, which may be attributed to the breakdown of protein and the formation of ammonia or ammonia-like compounds.

Effects of cold storage

Under refrigeration (< 5ºC), psychrotrophic bacterial populations are able to multiply on broiler carcasses and produce spoilage defects; however, the mesophilic bacteria that predominate on the carcass initially remain the same or decrease in number. This phenomenon may be explained by examining the metabolic changes that occur in these groups of bacteria as they are exposed to refrigerator temperatures.

Cellular lipids: Naturally, mesophilic bacteria cease to proliferate below a certain environmental temperature because as temperature decreases so does their cellular absorption of nutrients. Psychrotrophic bacteria species typically exhibit no such temperature-induced difference; hence, they are able to grow rapidly at refrigerator temperatures.

Lipase production: Research has demonstrated that the amount of lipase produced by psychrotrophic bacteria increases as a result of exposure of the bacteria to cold temperatures. This means that *Pseudomonas* is able to breakdown fat equally well when on chicken in the refrigerator or at room temperature, hence, its capability to spoil chicken.

Proteolytic activity: Research has shown that production of proteolytic enzymes by *Pseudomonas fluorescens* was higher when this bacterium was cultured at lower temperatures. This means that, as with fat, *Pseudomonas* is able to breakdown protein more effectively at refrigeration temperature than at room temperature and this makes the bacterium ideally suited to spoil chicken.

Shelf life: From time to time premature spoilage will occur. In order for companies to assess this problem, they often conduct aerobic plate counts on products. This microbiological method is inappropriate for this purpose because measuring mesophilic bacteria on chicken does not indicate what is happening with spoilage bacteria. Aerobic plate counts (APC) may miss up to 99.9% (3 logs) of spoilage bacteria on the surface of the product.

To measure spoilage bacteria, samples should be plated and incubated at 7ºC for 10 days. In this way, the bacteria that grow and produce colonies on the plate will be the ones responsible for spoiling the product.

1.4.6.1 Contamination and Spoilage of Eggs and Egg Products

Most freshly laid eggs are sterile, at least inside, but the shells soon become contaminated by fecal matter from the hen, by the cage or nest, by wash water if the eggs are washed, by handling, and perhaps by the material in which the eggs are packed. The total number of microorganisms per shell of a hen's egg has been reported to range from 10^2 to 10^7 with a mean of about 10^5. The types of microorganisms recovered from the shell are diverse. *Salmonella* species may be on the shell or in the egg as laid, build up during processing, and appear in significant numbers in frozen or dried eggs.

Factors influencing the contamination of eggshells

The spoilage of eggs is related to eggshell contamination and the ability of some bacteria to penetrate the egg. The type and level of egg contamination of the eggshell surface are related to the hygienic conditions in which the hens are reared, the breeding environment, the breeding practices, the housing system, the geographical area, and the season.

Contamination may also occur during egg transport and/or packaging in farms or in the conditioning centre, either through the environment or from one egg to another.

Even though the microflora of the eggshell surface varies, the spoilage flora of the egg content tends to be less diversified, highlighting the fact that the intrinsic egg barriers have a strong influence on the invasiveness of spoilage bacteria.

The cuticle, shell and shell membranes are barriers preventing the penetration of microorganisms from the surface into the egg content. Nevertheless, the cuticle which is resistant to water and microorganism penetration may crack rapidly over time or during egg manipulation.

The effectiveness of this protective coating is therefore limited. The shell, a calcified proteinic layer, represents a physical barrier but is rather ineffective because of the possible transfer of microorganisms through the pores, particularly if condensed water is present on the eggshell.

The presence of eggshell cracks or micro-cracks increases the risk of contamination. The manipulation of eggs, especially in the conditioning centres, increases the risk of egg cracking. The external and internal shell membranes represent effective filters composed of antibacterial glycoprotein fibres, which may play a role in protection against penetration.

In addition to these physical barriers, egg white, similar to an intracellular fluid, is an important line of defence against invading bacteria because it represents an unfavourable environment for microbial development (poor nutrient, exhibiting an alkaline pH, and high viscosity and heterogeneity), and because it contains several molecules expressing antimicrobial activities, such as lysozyme, ova transferrin, proteinase inhibitors (cystatin, ova mucoid and ovoinhibitor), and vitamin binding proteins (riboflavin binding protein, avidin- and thiamine-binding proteins).
The integrity of egg barriers is essential to prevent microbial penetration and proliferation.

Spoilage of Eggs
Some of the defects of eggs are obvious from their general appearance, others are shown by candling with transmitted light and some show up only in a broken egg.
Defects in the fresh egg
Fresh eggs may exhibit cracks, leaks, loss of bloom or gloss, or stained or dirty spots on the exterior as well as "meat spots", general bloodiness, or translucent spots in the yolk when candled.
Changes during egg storage: The changes that take place in eggs while they are being held or stored may be divided into those due to non-microbial causes and the changes caused by microorganisms.
a. Changes Not Caused by Microorganisms

1. Untreated eggs lose moisture during storage and hence lose weight. The amount of shrinkage is shown to the candler by the size of the air space or air cell at the blunt end of the egg, a large cell indicating much shrinkage.
2. The change in the physical state of the contents of the egg, as shown by candling or by breaking out the egg.
3. The albumin (egg white) becomes thinner and more watery as the egg ages, and the yolk membrane becomes weaker.
4. When an old egg is broken onto a flat dish, the thinness of the white is more evident, and the weakness of the yolk membrane permits the yolk to flatten out or even break. By contrast, a broken fresh egg shows a thick white and a yolk that stands up strongly in the form of a hemisphere.
5. During storage, the alkalinity of the white of the egg increases from a normal pH of about 7.6 to about 9.5. Any marked growth of the chick embryos in fertilized eggs also serves to condemn the eggs.
6. The poorer the egg, the more the movement is there of yolk and the nearer it approaches the shell when it is twirled during candling.

b. Changes Caused by Microorganisms

To cause spoilage of an undamaged shell egg, the causal organisms must do the following:

(1) Contaminate the shell.

(2) Penetrate the pores of the shell to the shell membranes (usually the shell must be moist for this to occur).

(3) Grow through the shell membranes to reach the white (or to reach the yolk if it touches the membrane).

(4) Grow in the egg white, despite the previously mentioned unfavourable conditions there, to reach the yolk, where they can grow readily and complete spoilage of the egg.

In general, more spoilage of eggs is caused by bacteria than by molds and the types of bacterial spoilage, or "rots," of eggs go by different name. The primary ones are:

i. **Green rots:** Caused primarily by *Pseudomonas fluorescens*, a bacterium that grows at 0ºC. The rot is named because of the bright-green colour of the white during early stages of development. This stage is noted with difficulty in candling but shows up clearly when the egg is broken. Odour is lacking or is fruity or "sweetish." The contents of eggs so rotted fluoresce strongly under ultraviolet light.

ii. **Colourless rots:** This may be caused by *Pseudomonas*, *Acinetobacter*, *Alcaligenes*, certain coliform bacteria, or other types of bacteria. These rots are detected readily by candling, for the yolk usually is involved, except in very early stages, and disintegrates or at least shows a white incrustation. The odour varies from a scarcely detectable one to fruity to "highly offensive."

iii. **Black rots:** Where the eggs are almost opaque to the candling lamp because the yolks become blackened and then break down to give the whole egg contents a muddy-brown colour. The odour is putrid, with hydrogen sulphide evident, and gas pressure may develop in the egg. Species of *Proteus* most commonly cause these rots, although some species of *Pseudomonas* and *Aeromonas* can also cause black rots. *Proteus melanovogenes* causes an especially black coloration in the yolk and a dark colour in the white. The development of black rot and of red rot usually means that the egg has at some time been held at temperatures higher than those ordinarily used for storage.

iv. **Pink rots:** Pink rots occur less often, and red rots are still more infrequent. Pink rots are caused by strains of *Pseudomonas*. They resemble the colourless rots, except for a pinkish precipitate on the yolk and a pink colour in the white.

v. **Red rots:** Red rots caused by species of *Serratia*, are mild in odour and are not offensive.

Spoilage of Eggs by Fungi: The spoilage of eggs by fungi goes through stages of mold growth that give the defects their names.

Pin spot molding: Very early mold growth is termed pin-spot molding because of the small, compact colonies of molds appearing on the shell and usually just inside it. The colour of these pin spots varies with the kind of mold. *Penicillium* species cause yellow or blue or green spots inside the shell, *Cladosporium* species give dark-green or black spots, and species of *Sporotrichum* produce pink spots.

Superficial fungal spoilage: In storage atmospheres of high humidity, a variety of molds may cause spoilage, first in the form of fuzz or "whiskers" covering the shell and later as more luxuriant growth. When the eggs are stored at near-freezing temperatures, the temperatures are high enough for slow mycelial growth of some molds but too low for sporulation, while other molds may produce asexual spores. Molds causing spoilage of eggs include species of *Penicillium, Cladosporium, Sporotrichum, Mucor, Thamniidium, Botrytis, Alternaria*, and other genera.

Fungal rotting: The final stage of spoilage by molds is fungal rotting, after the mycelium of the mold has grown through the pores or cracks in the egg. Jellying of the white may result, and coloured rots may be produced, e.g., fungal red rot by Sporotrichum and a black colour by Cladosporium, the cause of black spot of eggs as well as of other foods. The hyphae of the mold may weaken the yolk membrane enough to cause its rupture, after which the growth of the mold is stimulated greatly by the food released from the yolk.

Off-flavours sometimes are developed in eggs: Mustiness may be caused by a number of bacteria, such as *Achromobacter perolens, Pseudomonas graveolens,* and *P. mucidolens*. The growth of Streptomyces on straw or elsewhere near the egg may produce musty or earthy flavours that are absorbed by the egg. Molds growing on the shell also give musty odours and tastes. A hay odour is caused by *Enterobacter cloacae*. Fishy flavours are produced by certain strains of *Escherichia coli*. The "cabbage-water" flavour may appear before rotting is obvious. Off-flavors, such as the "coldstorage taste”, may be absorbed from packing materials.

Self- Assessment Exercises 2

1. List the sources of contamination in cereals

2. Describe the two types of microbial spoilage of vegetables

1.5 Summary

Food spoilage can occur as a result of the activities of enzymes, bacteria or fungi. The mixture of the food composition and packaging materials also influence food deterioration. Also, environmental, temperature and storage conditions play major roles in food deterioration.

Major causes of food deterioration include the following: growth and activities of microorganisms, principally bacteria, yeasts and moulds, activities of natural food enzymes, insects, parasites and rodents, temperature, both heat and cold, moisture and dryness, air and in particular oxygen, light, and time.

Extrinsic factors controlling the rate of food deterioration reactions are mainly: Effect of temperature; Effect of water activity; Effect of gas atmosphere; and Effect of light.

1.6 References/Further Readings

USDA. (2000). Fruit and Vegetable Programs. www.ams.usda.gov/fv/fvstand.htm

U.S. EPA. (2001). Guidance for Preparing Standard Operating Procedures. Office of Environmental Information, U.S. Environmental Protection Agency. EPA/240/B-01/004. http://www.epa.gov/quality1/qs- docs/g6-final.pdf

van Reeuwijk, L.P. (1998). Guidelines for quality management in soil and plant laboratories. FAO, Rome. Publication #M-90. http://www.fao.org/docrep/w7295e/w7295e00.htm

Wilson, L.G., Boyette, M.D., and Estes, E.A. (1995). Postharvest handling and cooling of fresh fruits, vegetables, and flowers for small farms. Part I: Quality maintenance. Horticultural Information Leaflet #800, North Carolina Cooperative Extension Service. http://ces.ncsu.edu/depts/hort/hil/hil-800.html

ASQ. (2000). ISO 9000 Standards for Quality. Amer. Soc. Qual. http://www.iso-9000-2000.com

Boutrif, E. and Bessy, C. (1999). Basic Approaches to consumer Protection – FAO/WHO Model Food Act – Control Procedures. Presented at Conference on International Food Trade – Beyond 2000: Science-based Decisions, Harmonization, Equivalence, and Mutual Recognition, Melbourne, Australia October 11-15.

Codex (2000). Codex Committee on Fresh Fruits and Vegetables. http://www.codexalimentarius.net

FAO. (1989). Prevention of Post-Harvest Food Losses: Fruits, Vegetables, and Root Crops a Training Manual. FAO Training

Series No. 17/2, Rome, Italy. http://www.fao.org/inpho/vlibrary/t0073e/T0073E00.htm

FAO/WHO. (1997). Codex Alimentarius Food Hygiene Basic Texts. Joint FAO/WHO Food Standards Programme, Codex Alimentarius Commission. Pub. # M-83.

FDA. (1998). Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables. U.S. Food and Drug Administration. http://www.cfsan.fda.gov/~dms/prodguid.html

1.7 **Possible Answers to Self-Assessment Exercises**

Answers to Self-Assessment Exercises 1

1. The four major factors that affect nutrient degradation to varying extents are light, oxygen concentration, temperature, and water activity.
2. The species of microorganisms which cause the spoilage of particular foods are influenced by two factors:

i. The nature of the foods

ii. Their surroundings/environment.

Answers to Self-Assessment Exercises 2

1. The sources of contamination in cereals are:

- Soil
- Air
- Insects
- Natural microflora of harvested grains

2. The microbial spoilage of vegetables is predominately of following types

i. **Spoilage due to pathogens:** The plant pathogens which infect stems, leaves, roots, flowers, fruits, and other parts of the plant causing different plant diseases.

ii. **Spoilage due to saprophytes:** Vegetables have general microflora inhabiting them which grows under certain conditions and spoil them. There are certain secondary invaders which may enter the healthy food or grow after growth of pathogens. It is well known that plant diseases are mostly caused by fungi.

UNIT 2 POST-HARVEST CHANGES IN FOOD

CONTENTS

2.1 INTRODUCTION

In this unit therefore we shall as simple as possible define what we mean by post-harvest losses and have a brief on post-harvest physiology that is simply put what happens to farm produce after harvest, or common activities that go on in the life of harvested produce. Harvested produce are living and care should be taken about what happen to them or changes that occurs after harvest.

2.2 Learning Outcomes

By the end of this unit, you will be able to:

- Discuss the scope of post-harvest losses
- Explain the fact that harvested produce are living tissues.
- Describe the post-harvest changes in produce
-

2.3 Post-Harvest Losses

The word harvest refers to the process of harvesting; gathering the ripened crop or the produce obtained from a farm. "Post-harvest" refers to events after harvest, when the harvested produce had been cut off from the source of nutrition from the parent plant. The word Physiology is a branch of biology that deals with the functions and activities of life or of living matter (as organs, tissues, or cells) and of the physical and chemical phenomena involved. Produce are plants parts that are of economic importance to man.

Post-harvest losses refer to all forms of reduction which may generally be in quantity or quality of harvested produce, from the point of harvest to the point of consumption of such produce. In other words, it is any form of reduction that occurs in the quality or quantity of harvested produce between the points of harvest till the time of consumption.

In order to have a good grasp of what we want to discuss, we should have an idea of the processes going on in harvested produce. Post-harvest changes occur in products such as banana, plantain, tomato, guava, oranges, yam tuber, carrot etc.

2.4 Post-harvest Physiology

Harvested produce are made up of living cells and tissues. Before such produce are harvested they are nourished by the parent plant through the process of photosynthesis. Because harvest produces are living, they exhibit all the characteristics of living things. Living things move as is obvious in animals, however, plants roots move towards water, they also move when blown by winds and so on. Respiration (the process whereby oxygen is taken in and carbon (IV) oxide (CO_2) is given out) takes place in all living things. Plant and animals also experience death. All living take in food for their nourishment, plants manufacture their food through the process of photosynthesis using energy from sunlight, water and other mineral nutrients from the soil; animals on the other hand take preformed food by feeding on plants and other animals. Animals respond to touch, the eyes also respond to light, skin respond to cold, heat and so on; in the same vein plant move in response to light (photosynthesis); some respond to touch, or gravity. Growth is the irreversible increase in height, volume, weight, area and so on; this is experienced by plants and animals. Excretion deals with removal or elimination of wastes from the body. Plants take in carbon (IV) oxide and give out oxygen. Animals sweat, pass out feces.

Reproduction deals with regeneration or giving birth to young ones in order to avoid extinction and ensure continuity.

Don’t forget what we are discussing any way the physiology of harvested produce and the fact that we claim that harvested produce are alive.

When a fruit is initiated it will continue to grow until maturity. A growing fruit is nourished by the food provided by the mother plant in the process of photosynthesis, the cells in the fruit takes in oxygen, in many fruits you have seeds for reproduction and the fruit can die. Now we can go ahead to discuss physiology of harvested produce.

One major activity that takes place in plants and harvested produce is Respiration. Respiration is defined as the process whereby oxygen is taken in and carbon (IV) oxide (CO_2) is given out. It leads to break down of harvested produce as stated in the equation: $C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O +$ Heat energy.

Carbohydrate or sugar in the harvested produce is used without any means of replacement; remember that green leaves continue to make more carbohydrate through the process of photosynthesis to replace that lost in respiration. On the other hand harvested produce continually use carbohydrate and lose water without any replacement. This eventually leads to ageing, death and decay. Air must be supplied adequately for normal respiration to take place. When air is in short supply to the extent that the oxygen level reduced from 20 per cent to two per cent, it has been reported that fermentation instead of respiration will take place. Fermentation leads to the production of alcohol and carbon (IV) oxide from sugar, the effects are production of unpleasant flavors and premature ageing. Lack of good ventilation will increase Carbon (IV) oxide concentration in the produce and if it rises from one to about five per cent, production of bad flavors occurs as well as internal break down of and failure of fruit to ripen.

Another major activity that also takes place in growing plants and harvested produce is transpiration or loss of water. Transpiration is the passage of water through the plant. This process maintains the high water content as well as the pressure needed for support. In fresh produce loss of water also occur, but this time without replacement. When there is up to 5-10 per cent reduction in fresh weight, harvested produce wilts and may become unusable. In other words, usable life of harvested produce can be extended by minimizing the rate of water loss. This can be achieved by keeping the harvested produce in a moist atmosphere.

Secondly, although good ventilation through the harvested produce is necessary to remove the heat of respiration, movement of air through the produce must be gentle because the faster the movement of air over the produce, the quicker the water loss. Good packaging material will reduce the rate of air movement over the produce. It should also be noted that rate of loss of water differs from produce to produce. One main factor that plays a role here is the ratio of the surface area to the volume of the produce. Produce with high surface area to volume ratio lose more water than those with lower surface area to volume ratio. That is the reason why produce like vegetable amaranth and other leafy vegetables readily lose water compared to tubers like sweet potatoes, yam and others

2.5 Causes of Post-Harvest in Produce

2.5.1 Injury

Injury sustained by produce especially mechanical injury at harvest is one of the causes of post-harvest losses. Mechanical injury occurs when tools used for harvest pierce or cut part of the produce, exposing the produce to higher moisture loss and infestation with disease. Mechanical injury can also occur as a result of crude methods of harvesting. Sometimes long poles are used to pluck off fruits from a tall tree while allowing the fruit to fall freely on the ground causing both external and internal injury which could kick start other forms of losses. Similarly, shaking-off fruits off a tree when many fruits are harvested will also result in mechanical injury.

2.5.2 Chilling Injury

Chilling injury is a disorder that occurs in especially tropical fruits and vegetables when they are stored in cold temperature above the freezing point most times between 10ºC-15ºC. Produce injury or damage mostly occurs before the freezing. Produce are kept in cold storage primarily to reduce the rate of their metabolic activities and slow down ripening and extend their shelf life. In other words like we have mentioned severally these food items are alive even though they have been detached from the parent plant. For produce that are injured at the chilling temperature, the tissues become weak because they are not able to carry out their normal functions. The seriousness of chilling injury a produce can sustain depends on how low the temperature is and how long the produce is exposed to the low temperature.

Some of the symptoms of chilling injury include surface lesions, the colour inside the produce would be different from normal, the tissues becomes water soaked and the produce will fail to ripe as it should. These signs are usually noticed after the produce are removed from the cold store and expose to a warm environment. Produce injured by chilling temperature are equally easily attacked by microorganisms.

There is also what is known as freezing injury; in which case ice crystals are formed in the tissues of produce when allowed to freeze. Produce that are not susceptible to chilling temperature are affected by freeing injury. Produce affected by chilling injury are also much more affected by freezing injury. Injured produce are not usually fit for sale but constitute a post-harvest loss.

2.5.3 Loss of Water

Loss of moisture directly reduces the weight of harvested produce and reduces the quality. Loss of moisture also paves way to entry of some disease causing organisms into the produce and this leads to post-harvest loss.

2.5**.4 Decay**

Decay occurs as a result of entry of pathogenic microorganisms into the harvested produce or on the surface of the produce. These microbes like bacteria, fungi and viruses can cause different types of diseases in the commodity. The disease causing microorganism could come in contact with the produce before harvest, from the soil through tiny holes on the tubers, they could also come in through wounds and bruises during harvest, injury during transportation or in storage if the store or storage materials are not properly disinfected.

2.5.5 Improper Curing

Curing is done especially in tuber crops to encourage new cells to form to cover up bruises and injuries sustained during harvest, before storage. If this is not properly done, post-harvest losses can be encouraged.

2.5.6 Sprouting and Rooting

Root and tuber crops are peculiar in their own and are propagated using the economic portion of the crops, e.g. yam and potatoes. Yam and potatoes undergo a period of dormancy after harvest. During this period once the general principles of safe storage is maintained the produce are kept intact. After the period of dormancy is expired, these produce begin to sprout and produce new shoot which will make use of the carbohydrate and water stored in the tubers for its growth and by so doing leading to both moisture loss and food loss. Loss of moisture also paves way to entry of disease causing organisms into the produce.

How long a tuber crop will remain dormant is therefore affected by whether it is wounded or not or the degree of injury, the temperature in the store house (high temperature favour high respiration); the moisture content in the store, and the air flow (the ventilation of the store and the carbon (IV) oxide in the store).

Self- Assessment Exercises 1

1. List the crop that post-harvest changes occur in
2. What is the effect of water loss on agricultural produce

2.6 Summary

A brief on post-harvest physiology that is simply put what happens to farm produce after harvest was discussed

In this unit we have defined post-harvest physiology as the study of the functions and activities of life in harvested produce and post-harvest losses refer to any form of reduction in the quality or quantity of harvested produce from the points of harvest to the time of consumption.

2.7 References/Further Reading

Jingtair, S. (2002). Post-harvest physiology of tropical fruits. Proceedings on tropical and subtropical fruits. In R. draw editor. Acta Hort. 575. Respiration- Food and Agricultural Organization. www.fao.org/docrep/t0073e/t0073e02.htm

2.8 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. Post-harvest changes occur in products such as banana, plantain, tomato, guava, oranges, yam tuber, carrot etc.

2. Loss of moisture directly reduces the weight of harvested produce and reduces the quality. Loss of moisture also paves way to entry of some disease causing organisms into the produce and this leads to post-harvest loss.

UNIT 3 FOOD CONTAMINATION

CONTENTS

3.1 Introduction

The process of food contamination takes several steps to get food from the farm or fishery to the dining table. We call these steps the food production chain. Contamination can occur at any point along the chain during production, processing, distribution, or preparation. Production means growing the plants we harvest or raising the animals we use for food. Most food comes from domesticated animals and plants, and their production occurs on farms or ranches. Some foods are caught or harvested from the wild, such as some fish, mushrooms, and game.

Examples of Contamination in Production: If a hen's reproductive organs are infected, the yolk of an egg can be contaminated in the hen before it is even laid. If the fields are sprayed with contaminated water for irrigation, fruits and vegetables can be contaminated before harvest. Fish in some tropical reefs may acquire a toxin from the smaller sea creatures they eat.

Processing means changing plants or animals into what we recognize and buy as food. It involves different steps for different kinds of foods. For crop, processing can be as simple as washing and sorting, or it can involve trimming, slicing, or shredding. Milk is usually processed by pasteurizing it; sometimes it is made into cheese. Nuts may be roasted, chopped, or ground. For animals, the first step of processing is slaughter. Meat and poultry may then be cut into pieces or ground. They may also be smoked, cooked, or frozen and may be combined with other ingredients to make a sausage.

Examples of Contamination in Processing

If contaminated water or ice is used to wash, pack, or chill fruits or vegetables, the contamination can spread to those items. During the slaughter process, germs on an animal's hide that came from the intestines can get into the final meat product. If germs contaminate surfaces used for food processing, such as a processing line or storage bins, germs can spread to foods that touch those surfaces.

Food distribution means getting food from the farm or processing plant to the consumer or a food service facility like a restaurant, cafeteria, or hospital kitchen. This step might involve transporting foods just once, such as trucking produce from a farm to the local farmers' market. It might involve many stages, for instance, frozen hamburger patties might be trucked from a meat processing plant to a large supplier, stored for a few days in the supplier's warehouse, trucked again to a local distribution facility for a restaurant chain, and finally delivered to an individual restaurant.

Examples of Contamination in Distribution: If refrigerated food is left on a loading dock for long time in warm weather, it could reach temperatures that allow bacteria to grow.

Fresh produce can be contaminated if it is loaded into a truck that was not cleaned after transporting animals or animal products.

Food preparation means getting the food ready to eat. It may occur in the kitchen of a restaurant, home, or institution. It may involve following a complex recipe with many ingredients, simply heating and serving a food on a plate, or just opening a package and eating the food.

Examples of Contamination in Preparation: If a food worker stays on the job while sick and does not wash his or her hands carefully after using the toilet, the food worker can spread germs by touching food. If a cook uses a cutting board or knife to cut raw chicken and then uses the same knife or cutting board without washing it to slice tomatoes for a salad, the tomatoes can be contaminated by germs from the chicken. Contamination can occur in a refrigerator if meat juices get on items that will be eaten raw.

Mishandling at Multiple Points

Sometimes, by the time a food causes illness, it has been mishandled in several ways along the food production chain. Once contamination occurs, further mishandling, such as undercooking the food or leaving it out on the counter at an unsafe temperature, can make a foodborne illness more likely. Many germs grow quickly in food held at room temperature; a tiny number can grow to a large number in just a few hours. Reheating or boiling food after it has been left at room temperature for a long time does not always make it safe because some germs produce toxins that are not destroyed by heat.

Foods can become contaminated by microorganisms (bacteria, fungi and viruses) from many different sources during the food preparation and storage process. Cross contamination of food is a common factor in the cause of food borne illness. Preventing cross contamination is one step to help eliminate food borne illness. It is important to protect food from risk of contamination to prevent food poisoning and the entry of foreign objects.

3.2 Learning Outcomes

By the end of this unit, you will be able to:

- Write the major sources and types of food contamination
- Discuss the causes and prevention of cross contamination of foods
- Discuss the control of contamination in various agricultural produce.

3.3 Types of Food Contamination

3.3.1. Biological Contamination

Biological contamination is one of the common causes of food poisoning as well as spoilage. Contamination of food items by other living organisms is known as biological food contamination. During biological contamination, the harmful bacteria spread on foods that we consume. Even a single bacterium can multiply very quickly when they find ideal growth conditions. Not just bacteria, but also their process of multiplying can be quite harmful to humans.

Bacteria are commonly found in the following places:

i. Dust
ii. Raw meat
iii. The air
iv. The human body
v. Pets and pests
vi. Clothes of food handler
vii. Kitchen Cloths

The best way to avoid food contamination is by washing the food items with KENT vegetable and fruit cleaner and washes the kitchen cloths on a regular basis.

If food is consumed that has been contaminated by certain, harmful bacteria (pathogenic bacteria) or their toxins, food poisoning may result. Bacteria are responsible for most food poisoning cases. Symptoms of food poisoning may include vomiting, diarrhoea, fever and abdominal pain. The symptoms may take some time to occur depending on the type of bacteria. In general, the bacteria must grow in the food to produce sufficient numbers to infect the body, multiply within the intestine and cause illness. Alternatively, toxins may be produced in the foodstuff or within the intestine, to produce symptoms very soon after ingestion. It is important to remember that foods contaminated with pathogenic bacteria will look, taste and smell perfectly normal.

Control of Bacterial Contamination

i. Prevent cross-contamination: Cross-contamination occurs when bacteria are transferred onto food either directly (when raw and cooked food comes into direct contact, sneezing or coughing onto food) or indirectly (via a vehicle such as from dirty utensils, pests, hands etc.)

ii. Separate raw and cooked foods: Prepared and cooked foods should be stored separate from raw foods and unprepared vegetables to reduce the risk of cross-contamination. If this is not possible, raw food and unprepared vegetables should always be stored at the base of the refrigerator.

iii. Keep stored foods covered.

iv. Prevent animals and insects entering the food room.

v. Keep food preparation areas and utensils clean.

vi. Wash hands frequently, particularly after using the toilet, handling raw foods, handling refuse, blowing your nose, combing your hair and after smoking.

vii. Keep cuts, boils etc., covered with a waterproof dressing.

viii. Do not handle food if suffering from symptoms of diarrhea or vomiting and notify your supervisor immediately.

To multiply/grow, bacteria require food, warmth, moisture and time. By removing one or more of these criteria the growth of bacteria can be slowed or even stopped. Therefore foods should

i. be stored at safe temperatures (either cold below 8°C or hot above 63°C)

ii. be cooked thoroughly

iii. not be prepared too far in advance

iv. not be kept at room temperature for any longer than necessary

v. be heated thoroughly and stirred during heating

vi. be cooled within 1½ hours and refrigerate.

vii. Foods that are dry should be kept dry and prevented from becoming moist.

3.3.2 Physical Contamination

When harmful objects contaminate the food, it leads to physical contamination. At times, food items can have both physical and biological contamination. Physical contaminants such as rats, hair, pests, glass or metals can contaminate food and make it unhealthy. Some of the safety tips that you can follow when handling food items to prevent food contamination are:

i. Tie your hair when handling food

ii. Clean away cracked or broken crockery and utensils to avoid contamination

iii. Keep your fingernails short or wear clean gloves when handling food

iv. Wash fruits and vegetables with KENT Vegetable and Fruit Cleaner to remove dirt

v. Wear minimum jewelry when preparing food

Physical contamination can occur at any stage of the food chain and therefore all reasonable precautions must be taken to prevent it.

Examples of physical contamination include:

i. Pieces of machinery which can fall into food during manufacture. Most manufacturers protect against this type of contamination by installing metal detectors on the production lines which reject food if anything metallic is present.

ii. Stones, pips, bones, twigs, pieces of shell.

iii. Foreign objects can enter food during handling so care must be taken to adhere to good food handling practices (e.g. do not wear jewelry or smoke in a food room).

3.3.3 Chemical Contamination

Chemical contaminants are one of the serious sources of food contamination. These contaminants can also lead to food poisoning. Pesticides present in fruits and vegetables are one of the main sources of contamination. In addition, kitchen cleaning agents, food containers made of non-safe plastic and pest control products also lead to food contamination. Though we make it a point to wash fruits and vegetables thoroughly, however, plain water can't remove all the contaminants. The smart kitchen appliance uses ozone disinfection technology that removes contaminants from the surface of the fruits and vegetables to make it safe for consumption.

Chemicals, including pesticides, bleach and other cleaning materials can contaminate food if not used carefully. For example, store cleaning fluids separate to foods to prevent tainting and contamination if there is a spillage.

Toxicity of Heavy Metals

The toxicity of heavy metals increases sharply in the order zinc, cadmium, mercury. The toxicity of zinc is low. In drinking water zinc can be detected by taste only when it reaches a concentration of 15 parts per million (ppm); water containing 40 parts per million zinc has a definite metallic taste. Vomiting is induced when the zinc content exceeds 800 parts per million. Cases of fatal poisoning have resulted through the ingestion of zinc chloride or sulfide, but these are rare. Both zinc and zinc salts are well tolerated by the human skin. Excessive inhalation of zinc compounds can cause such toxic manifestations as fever, excessive salivation, and a cough that may cause vomiting; but the effects are not permanent.

Compared with those of zinc, the toxic hazards of cadmium are quite high. It is soluble in the organic acids found in food and forms salts that are converted into cadmium chloride by the gastric juices. Even small quantities can cause poisoning, with the symptoms of increased salivation, persistent vomiting, abdominal pain, and diarrhea. Cadmium has its most serious effect as a respiratory poison: a number of fatalities have resulted from breathing the fumes or dusts that arise when cadmium is heated. Symptoms are difficult or laboured breathing, a severe cough, and violent gastrointestinal disturbance.

Mercury and its compounds are highly toxic. They can be handled safely, but stringent precautions must be taken to prevent absorption by inhalation, by ingestion, and through the skin. The main result of acute poisoning is damage to kidneys.

3.4 Cross-Contamination

Many of us are not aware of cross-contamination; however, this type of contamination can lead to a number of health problems. Cross-contamination takes place when pathogens are transported from any object that you use in the kitchen. Dirty kitchen clothes, unclean utensils, pests, raw food storage can lead to cross-contamination. Here are some of the ways to avoid cross-contamination:

Personal Hygiene: Thoroughly wash your hands and face when handling food. Coughing, sneezing or even touching your hair can lead to cross-contamination

Utensils: Use separate utensils to prepare different types of foods. Avoid using the same chopping board and knife for ready to eat foods

Storing of Food: Raw foods should not come in contact with ready to eat foods. Cover and store raw foods below cooked foods to prevent cross-contamination.

Disposing Waste: Make sure you store and seal garbage correctly to prevent cross-contamination. Clean and sanitize the waste bins to prevent infestation risk.

Cross contamination is the contamination of a food product from another source. There are three (3) main ways cross contamination can occur: Food to food, Equipment/Utensil to food and People to food.

3.4.1 Food to Food

Food can become contaminated by bacteria from other foods. This type of cross contamination is especially dangerous if raw foods come into contact with cooked foods. Here are some examples of food to food cross contamination: In a refrigerator, meat drippings from raw meat stored on a top shelf might drip onto cooked vegetables placed on a lower shelf. Raw chicken placed on a grill touching a steak that is being cooked.

3.4.2 People to Food

People can also be a source of cross contamination to foods. Some examples are: Handling foods after using the toilet without properly washing your hands. Touching raw meats and then preparing vegetables without washing hands between tasks. Using an apron to wipe your hands between handling different foods, or wiping a counter with a towel then using the towel to dry your hands.

3.4.3 Equipment to Food

Contamination can also be passed from kitchen equipment and utensils to food. This type of contamination occurs because the equipment or utensils were not properly cleaned and sanitized between each use. Some examples are: Using unclean equipment such as slicers, can openers and utensils to prepare food. Using cutting boards and the same knife when cutting different types of foods, such as cutting raw chicken followed by salad preparation.

Storing a cooked product, such as a sauce, in an unsanitized container that was previously used to store raw meat.

3.4.4 Preventing Cross Contamination

1. Wash your hands between handling different foods as well as before and after handling each food.
2. After cutting raw meats, wash hands, cutting board, knife, and counter tops with hot, soapy water.
3. Wash and sanitize all equipment and utensils that come in contact with food.
4. Marinate meat and poultry in a covered dish in the cooler.
5. Avoid touching your face, skin, and hair or wiping your hands on cleaning cloths.
6. Use a utensil only once to taste food that is to be sold or served.
7. Never store food or packages directly on the floor.
8. Keep wiping cloth for food contact surfaces and tabletops in sanitizer bucket when it is not being used for wiping.
9. Cloths used for wiping up raw animal juices must be kept separate from cloths used for other purposes.
10. Avoid bare hand contact with foods that are ready-to-eat (foods that require no further preparation or cooking before serving; e.g. relish trays and birthday cakes.). Use utensils, deli tissue, spatulas, tongs, single-use gloves or dispensing equipment.
11. Store food properly by separating washed or prepared foods from unwashed or raw foods.
12. Try preparing each type of food at different times and then clean and sanitize food contact surfaces between each task.

Self- Assessment Exercises 1

1. Outline the ways to avoidcross-contamination in foods.
2. Where bacteria are commonly found?

3.5 Summary

Food contamination can be prevented by identifying sources of contamination, namely: (i) physical, (ii) chemical or (iii) cross – contamination.

There are three major types of food contamination: (a) Physical contamination (b) biological contamination and (c) chemical contamination. Field produce like citrus, peas and beans, peppers, vegetables and tomatoes can be preserved from contamination by the techniques applied during post-harvest storage.

3.6 References/Further Readings

FAO. (1989). Prevention of Post-Harvest Food Losses: Fruits, Vegetables, and Root Crops a Training Manual. FAO Training Series

No. 17/2, Rome, Italy. www.fao.org/inpho/vlibrary/t0073e/T0073E00.htm

FAO/WHO. (1997). Codex Alimentarius Food Hygiene Basic Texts. Joint FAO/WHO Food Standards Programme, Codex Alimentarius Commission. Pub. # M-83.

FDA. (1998). Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables. U.S. Food and Drug Administration. http://www.cfsan.fda.gov/~dms/prodguid.html

FDA. (2001). FDA Publishes Final Rule to Increase Safety of Fruit and Vegetable Juices. Food and Drug Administration News Release, U.S. Food and Drug Administration. http://www.fda.gov/bbs/topics/NEWS/2001/NEW00749.html

Food Science Australia. (2000). Packaged Minimally-Processed Fresh-cut Vegetables. In Food Safety and Hygiene- A Bulletin for the Australian Food Industry, Food Science Australia. http://www.dfst.csiro.au/fshbull/fshbull21.htm

FSIS. (1996). FSIS Pre-HACCP Standard Sanitation Operating Procedures Reference Guide. Food Safety and Inspection Service, U.S. Department of Agriculture.

Gardner, S. (1993). Consumers and Food Safety: A Food Industry Perspective. In Food, Nutrition, and Agriculture – Consumer Participation in Food Control.
http://www.fao.org/docrep/v2890t/v2890t00.htm

Gould, W.A. and Gould, R.W. (1993). Total Quality Assurance for the Food Industries. 2nd ed. CTI Publications, Baltimore, MD, USA.

IAFIS. (1999). Food Standards Library. www.iafis.org/fiic/stan/stan1.htm

IFT. (2001). Introduction to the Food Industry – Lesson 1. Food Quality and Safety Assurance. http://www.ift.org/education/food_industry/lesson1.shtml

Kitinoja, L. and Kader, A.A. (1995). Small-scale Postharvest Handling Practices – A Manual for Horticultural Crops. 3rd Edition. University of California, Davis. http://www.fao.org/wairdocs/x5403e/x5403e00.htm

Lindenmayer, I. (1999). Harmonization of Food Regulations and Food Quality/Safety Measures based on Codex Standards, Guidelines, and

Recommendations. Presented at Conference on International Food Trade – Beyond 2000: Science-based Decisions, Harmonization, Equivalence, and Mutual Recognition, Melbourne, Australia October 11-15.

Pattee, H. E. (1985). Evaluation of Quality of Fruits and Vegetables. AVI, Van Nostrand Reinhold Co., New York.

Potter, N. N. and Hotchkiss, J.H. (1995). Food Science. 5th ed. Chapman & Hall, New York.

3.7 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. Here are some of the ways to avoid cross-contamination:

Personal Hygiene: Thoroughly wash your hands and face when handling food. Coughing, sneezing or even touching your hair can lead to cross-contamination

Utensils: Use separate utensils to prepare different types of foods. Avoid using the same chopping board and knife for ready to eat foods

Storing of Food: Raw foods should not come in contact with ready to eat foods. Cover and store raw foods below cooked foods to prevent cross-contamination.

Disposing Waste: Make sure you store and seal garbage correctly to prevent cross-contamination. Clean and sanitize the waste bins to prevent infestation risk.

2. Bacteria are commonly found in the following places:

viii. Dust
ix. Raw meat
x. The air
xi. The human body
xii. Pets and pests
xiii. Clothes of food handler and Kitchen Cloths

UNIT 4 ADULTERATION OF FOOD

CONTENTS

4.1 Introduction

Food adulteration is an act of intentionally debasing the quality of food offered for sale. It is a process in which the quality of food is lowered or reduced by replacing food ingredient or addition of non-authenticated substances or removal of a vital component from food for the sake of earning profit or due to other incidental reasons. Food adulteration ultimately deceives consumers and leads various health risks. Nowadays, it is very difficult to find a sector of food industry which is free of adulteration. Because of that it is important for the consumer to know the common adulterants and their effect on health since the increasing number of food producers and the outstanding amount of foodstuffs import enables the producers to mislead and cheat consumers. Adulterants are chemical substances which should not be contained within our food or beverage, and may be intentionally added to more expensive substances to increase visible quantities and reduce manufacturing costs, or for some other deceptive or malicious purpose. As the usage of adulterants has increased tremendously in recent years, there has been a growing interest among consumers in the safety and traceability of food products. Adulterants can also be elaborated as chemical substances which should not be contained within a given food or beverage, and but, may be intentionally added to more expensive substances to increase visible quantities and reduce manufacturing costs, or for some other deceptive or malicious purpose. The act of adulteration was more common in societies from very ancient time with few legal controls on food quality due to poor or nonexistent monitoring by authorities. Sometimes the act of adulteration may even extended to exceedingly dangerous chemicals and poisons.

4.2 Learning Outcomes

By the end of the unit, you will be able to:

- Analyse Food Adulteration and adulterant
- Write the reasons for adulteration
- Write the types of adulteration
- Discuss the adulterants

4.3 Food Adulteration

4.3.1 Reasons for Adulteration

Adulteration is present in society from a long time but it was not noticed due to its small scale use and its low impact. But at the present era, economic adulteration is a long term problem affecting the food industry at its most drastic level. According to survey, adulteration were detected in milk to the tune of 70% with water, turmeric powder-43% with chalk powder, red chilli powder-100% with artificial colour, sugar 37% with chalk powder etc. The main reason that attracts adulteration is for boosting their cash income by increasing its volume. Even though increasing their profit margins initiated adulteration done by some selfish producers, processors and retailers, the main cause for adulteration is dishonesty and lack of accidental quality assessment on products As world population is growing at alarming rate, food is often adulterated to meet the needs of this growing population and to feed the large scale population. Another motive for faking and adulteration of goods and services is outsourcing to offshore producers. Outsourcing became possible because comparatively labour is cheap in some countries and this is also what makes product faking easy since the cost of producing is far less compared to the super normal profits being made. Generally foods are adulterated for the following six reasons. These are:-

1. When the demand is more than the supply in the market
2. To come at par with the market competitors by lowering the cost of production
3. The greed for increased profit margins
4. The common man cannot afford food items with their original constituents
5. Lack of trained manpower with outdated food processing techniques
6. No idea about the disease outbreaks caused due to adulterated food products.

4.3.2 Types of Adulteration

Adulteration is the act of debasing product with the object of counterfeiting a pure or genuine commodity or of substituting an inferior article for a superior one in order to gain an illegitimate profit. The four ways of adulteration:

i. Addition of extraneous matter, e.g. addition of sand to food grains and water to milk

ii. Mixing inferior quality material with a superior one, e.g. mixing used/spent tea leaves with fresh tea leaves

iii. The use of prohibited dyes and preservatives, e.g. coloring of spices

iv. Extraction of valuable ingredients, e.g. abstraction of fat from milk or oils from spices.

Food is said to be adulterated if any of the following happened to it:

i. A substance is added which decreases its value or injuriously affects it.

ii. Less expensive or inferior substances are substituted wholly or in part.

iii. Any valuable constituents have been subtracted either wholly or in part.

iv. If it is counterfeiting (imitation).

v. If coloured or otherwise treated, to improve its appearance with stuff injurious to health.

vi. No matter what the reason is, if its quality is below the standard.

Food in general is adulterated for different reasons. Some organizations or individuals in food supply chains are adding adulterants to foods for improving the appearance to get better price by cheating buyers of the products. Food can also adulterated for increasing volume, preserving or others. Generally, adulterations can be intentional and unintentional.

a. Intentional Adulteration

Intentional food adulteration is a purposefully performed type of adulteration act and is usually done for financial gain. The most frequent type of adulteration of this category is colour adulteration. The examples of the intentional adulteration are the addition of water to liquid milk, extraneous matter to ground spices, or the removal or substitution of milk solids from the natural product. It includes adding things like sands, marble chips, stones, mad, other filth, chalk powder, water, mineral oil, and harmful colour to earn some unfair profit. Addition of water or urea to liquid milk, extraneous matter to ground spices, addition of argemone seeds to mustard seeds, washing powder to ice creams, chalk to sugar, water to honey, chicory to coffee, white powered stone to common salt, argemone oil to groundnut oil are all intentional adulterants. It is dangerous because, amounts of nutrients deducted and extraneous substances added into food items that are done by business oriented people just forgetting the humanity behind of money making mentality.

Research revealed that olive oil, milk, honey, saffron, orange juice, coffee and apple juice are the seven most likely food ingredients to be targets for intentional or economically aggravated use of adulterants in food, or food fraud as of the first U.S. public database created to compile information on risk factors for food fraud. Calcium carbide used in mangoes, bananas, copper sulfate used to ripen fruits faster, oxytocin a hormone used for faster growth of Pumpkin, watermelon, gourds, cucumber, wax adds shine on apples and pears, cheap green colors containing chemicals such as metallic lead applied to bitter gourd and leafy vegetables to give fresh color, pesticides and herbicides used excessively for growing fruits and vegetables can all be considered adulterants if not well communicated to consumer.

Incidental Adulteration

Unintentional (incidental) adulteration is a result of ignorance or the lack of facilities to maintain food quality. This may be caused by leak out effect from pesticides and fertilizers. Inappropriate food handling and packaging methods can also result in these types of adulterations. Accidental food adulteration as the name imply occurs accidentally (incidentally) without our knowledge. Studies elaborate that, a variety of green vegetables is grown in areas of industries and these areas have high levels of industrial pollutants, including heavy metals, which are absorbed by the plants and hence, food adulteration occurs accidentally is expected. Pesticide residues, droppings of rodents, larvae in foods are examples of adulterants under this category. This type of adulteration is brought due to lack of proper hygienic conditions of food products and drinks throughout production site to consumption table. The producers or traders are not in position to add different adulterants but the ways the products are produced, handled, passed, and processed, stored, transported and marketed may be the places where they were contaminated or adulterated since any substance without its original is extraneous to the product. These includes: residual pesticides, tin from cans, rodent droppings, preservatives, mercury from effluents, lead from water, etc.

Metallic Contaminants

Metallic contaminants may enter the food supply chain through environmental contamination or during food production process and they may be present in food in trace amount. Arsenic from pesticides, lead from water, and effluent from chemical industries, tin from cans are some of the metallic contaminants which could be considered another incidental type of adulterants in foods. The mercury from effluents, lead from water and similar contaminants are also among metallic adulterants.

Natural Adulteration

The natural adulteration is also another type of adulteration which could take place in foods due to the presence of different chemicals, organic compounds or radicals naturally occurring in foods which are injurious to health and are not added to the foods intentionally or unintentionally.

From different types of natural adulterations some of the examples are toxic varieties of pulses, mushrooms, green and other vegetables, fish and seafood which might be called as anti-nutrients in some of cases. Many varieties from species of marine fish are known to be toxic of which many are among edible varieties. The act of food adulteration can also be categorized as replacement, addition or removal. Replacement can be absolute or partial substitution of a food component or valuable authentic constituent with less expensive substitute with the intention of circumventing on origin and false declaration of the process in general. Addition on the other hand is the inclusion of small amount of non-authenticated substances to mask inferior quality ingredient. The removal type of adulteration is taking away of authentic and valuable constituents without purchasers' knowledge. These all are done for the economic gain. Adulteration can also occur during production of organic, genetically modified and irradiating foods.

Adulteration in Organic Foods

In case the food is claimed to be organic, it needs to be grown and manufactured in a manner that adheres to standards set by the respective country they are sold in. In an organic type of farming there is no use synthetic pesticide into the environment. The most common pesticides, accepted for restricted use by most organic standards include Bt, pyrethrum and rotenone. Therefore, any organic food not fulfilling the standards is adulterated.

Adulteration during Irradiating the Foods

In food irradiation, the ionizing radiation like radionuclide Cobalt-60 is applied to food for destroying and checking the multiplication of microorganisms, bacteria, viruses, or insects that might be present in the food and for sprout inhibition, delay of ripening and improvement of rehydration as well. For irradiating the foods the quantity of dosage is very much important. In ionizing radiation, there are disruption of internal metabolism of cells, DNA cleavage, formation of free radicals, disruption of chemical bonds, high capital costs, possible development of resistant microorganism, inadequate analytical procedures to detect irradiation in food, and public resistance. If this irradiation is used at the level that it can be over dosed, then, it is obvious that it will sever health hazards and hence can be considered adulteration.

Adulteration during Production of Genetically Modified Foods

Genetically modified organisms (GMOs) are organisms in which the genetic material (Nucleic Acid (NA)) has been changed in a manner that does not happen in nature. Combining genes from different organisms is said to be genetic modification (GM). The GM products include medicines, vaccines, food and food ingredients, feeds and fibers. Though GM foods are developed and marketed because there is some perceived advantage either to the producer or consumer of these foods. However, there are safety issues including allergens, transfer of antibiotic resistance markers, and unknown effects can happen. Unless communicated to users, GMO food could be one form of adulterations.

4.3.3 Food Adulteration and Its Consequence

Health Problems Related To Adulteration

Adulterated foods can leads to different health problem after consumption and considered as one of the major problem of everyday life. For example, addition of argemone seeds to mustard seeds can cause loss of vision and heart diseases. Adulteration exposes the society to many diseases ranging from mild to life threatening ones. For example, asthma, skin diseases and cancer caused due to intake of fish, fruits, meat or milk adulterated with chemicals like formalin. Human health is highly sensitive to food adulteration and sometimes shows immediate side effects like diarrhea, dysentery and vomiting. For example, coffee powder substituted with date seed powder or tamarind can cause diarrhea. Scientist has reported that a chunk of the green leafy vegetables sold in Chennai is found to contain toxic metals that have the potential to harm various organs of the body. It is common in almost all developing countries. And its ugly face is come out in the form of its harmful effects as stomach disorder, giddiness and join pain, diarrhea, liver disorder, dropsy, gastrointestinal problems, respiratory diseases, cardiac arrest, glaucoma carcinogenic effects, paralysis etc. Therefore, health concern related to food adulteration as can be understood to include food poisoning, Stomach ache, indigestion, loose stools, Cough, fever, Vomiting or nausea, Apthae in mouth, out of infection from adulterated food, etc.

Economic Impact of Adulteration

Adulterant is rampant in poor strata of society due to consumer’s illiteracy and ignorance of their rights and responsibilities towards food adulteration. High incidence of food borne illness is found in families who consume adulterated food. Thus, adulterated foods may be profit for those who are adulterating while it is not only expense of money for consumer but also leads to illness as well. With time, acceptance of foods in the market decreases due to destruction in originality of adulterated and this is economic loss.

4.3.4 Food Products Prone To Adulteration

There are various food items that are prone for adulteration as revealed by reports of different scientists across the world. That means it may be difficult to get a food items, may be flour, pulse, oil, fruit, vegetable, milk, sweet, spices, tea, coffee, honey, bakery item, chocolate, fruit juice, etc. which is free from one or the other forms of adulterants. Even animal feed like cake as protein supplement for lactating animals is adulterated which accounts about 90 percent of un-branded loose forms.

4.3.5 Detection Mechanisms of Adulterated Food

The mechanisms of identifying the usage of adulterants in foods depends on physical, chemical, biochemical, and other techniques. All these methods, which have replaced the early organoleptic and other empirical tests, are continuously updated because food adulteration is interminable, and new problems are always arising. Different types of analytical procedures are usually employed for most cases of adulteration so that the analyst has the flexibility to choose the appropriate one (number of samples to be analyzed, sensitivity required, etc). For example, red wine adulterated with the juice of bilberries or elderberries produced a deep blue precipitate with lead acetate. Also, starch in rice flour or wheat flour often added to thicken cream and could be recognized by the blue colour produced by a dilute solution of iodine test in aqueous potassium iodide.

4.3.5.1 Chemical and Biochemical Methods

There are different designed chemical and biochemical methods for detection of adulterants which can be categorized as chromatography based, spectroscopy and immunology based and electrophoresis based. The basic analytical approach involves various steps including extraction with a suitable solvent, cleanup for removal of interfering matrix components, chromatographic separation and selective detection. These and other methods of detection of adulterants can be done by following the respective procedures of each of the methods.

High performance liquid chromatography (HPLC) can be used as a quality control tool as it can separate various chemical constituents from mixtures. It is also used for characterizing food products or to detect adulteration. Its use in adulterant detection lies in its capacity to separate mixture of chemicals. For example, among the analytical techniques of adulterant detection, HPLC is the most widely used technique and the procedure follows the normal procedure of chemical determination by this instrument.

Gas chromatography (GC) is an extra apparatus for identification of adulterants and is used for separating volatile organic compounds. GC along with mass spectroscopy (MS) and Fourier transform infrared spectroscopy (FTIR) has been widely used for adulterant detection as these are non-destructive techniques with respect to the sample. Gas chromatography is generally used to discriminate among different varieties of the same product, adulteration detection, and organic compound authentication and identification. Among the spectroscopic techniques, near infrared spectroscopy (NIR) helps in rapid detection of adulterants in raw material but is unable to identify the contaminant. The nuclear magnetic resonance (NMR) will not only detects an adulterant but also provides structural identification of the contaminant. Atomic Absorption Spectrometry can be utilized as validation method for analysis of lead in all foods except oils, fats and extremely fatty products. A combination of chromatographic and spectroscopic techniques has also shown a high potential for detection of adulterants, for example, GC-MS has shown potential to detect honey adulteration with commercial syrups. The indirect enzyme linked immune-sorbent assay (ELISA) can also be used for the detection and quantification of bovine milk adulteration in goat's milk. It has been observed that ELISA can be successfully used to determine adulteration of milk samples and thus ELISA kits will help in routine inspection of milk. Milk and milk products adulterated with starchy products can be identified through digestion of starch by first boiling 2-3 ml of sample in 5 ml of water, cooling and adding 2 to 3 drops of iodine and then formation of blue colour indicates the presence of starch.

Milk adulteration by starchy source can be identified by heat treatment. While heat is applied, the starch will galvanize and this will be an index. If iodized salt is in need and there is worry about whether the available salt iodized or not, it can simply be checked as follows. The procedures include cutting a piece of potato, add salt and wait for a minute, add two drops of lemon juice, blue colour will develop if it is iodized salt while no blue colour if not.

Proximate analysis of a foodstuff can also indicates the extent of abstraction for the main compositional components; moisture, fat, protein, carbohydrates, fiber, and ash. However, proximate analysis of adulterated food alone cannot answer problems of authenticity or speciation. This may be because, combination both qualitative and quantitative analysis of foods are important to be used for detection of adulteration of food ingredients and products. Predominantly, adulteration can be detected from the presence of minor components that occur in the adulterant and not in the food itself. Trace chemical analysis is indispensable to evaluate the purity. Data banks of authentic values that account for seasonal, regional or other variation may support authenticity testing in some cases. Detection of food adulterant is more difficult when both adulterant and the food itself have approximately the same chemical formula.

There are different approaches to detecting adulterants by overcoming the problem:

1. The primary approach consists of determining the ratio between some chemical constituents and assumes these ratios are a constant component of the particular food.
2. Searching for a specific marker in the product, which could be a chemical constituent or morphological component that proves either the adulteration or authenticity of the food is another alternative approach.
3. The other method consists of using analytical techniques derived from physical analysis by considering the whole of the sample to show the effects of the adulteration on the physicochemical properties of the sample.

The different detection methods can be categorized as physical and chemical method.

4.3.5.2 Physical Methods

There are various physical methods for detection of adulteration including microscopic and macroscopic visual structural analysis as well as analysis of food by analyzing the physical parameters like morphology, texture, solubility, bulk density etc. but these methods do not guarantee qualitative adulterant detection. For instance, microscopic examination of some spices namely cumin, coriander, chilies, and cloves lead to easy detection of extraneous starch in these powdered spices. In grain, detection of adulteration with different impurities (dust, stones, straw, weed seeds, damaged grain, weevil grain, insects, rodent hair and excreta, etc.) could be detected by taking small quantity of sample in a glass plate and examining the impurities visually because, pure food grains will not have any such impurities.

4.3.5.3 Sensory Methods

Conventionally, sensory methods have been employed in detecting some adulteration. Sensory methods however have not been incorporated yet into legislation for the detection of food adulteration, although routine analysis of a sample always includes the examination of its organoleptic characteristics. International organizations such as the International Standards Organization (ISO), American Society for Testing Materials (ASTM), and others have developed and recommended sensory methods for foods in general and for particular commodities. Such methods are useful in trade (grading of goods) and the management of resources. Moreover, the US Food and Drug Administration (FDA) has accepted results of sensory panel tests as prima facie evidence of product efficacy, and in some cases, legal decisions in the USA have relied exclusively upon sensory evaluation data. The limitations concerning the application of sensory methods for the detection of adulteration are fewer now that multivariate statistical techniques are employed. With these methods, sensory data are better evaluated, and more reliable conclusions can be drawn. The approach has been meaningfully applied to classify coffee, tea, and alcoholic beverages.

Self- Assessment Exercise

1. State four ways of adultrating a food
2. List food products that are prone to contamination

4.4 Summary

Food adulteration is a process in which the quality of food is lowered or reduced by replacing food ingredient or addition of non-authenticated substances or removal of a vital component from food for the sake of earning profit or due to other incidental reasons. It can be intentional, unintentional (accidental), or natural. The adulterants differ from product to product and its presence in food can be detected using physical methods, sensory methods, etc.

Food adulteration is a process in which the quality of food is lowered or reduced by replacing food ingredient or addition of non-authenticated substances or removal of a vital component from food for the sake of earning profit or due to other incidental reasons. It can be intentional, unintentional (accidental), or natural and can occur at any stage of the produce. Adulteration is a public health issue as it poses a health threat to consumers.

4.5 Glossary

Adulteration: an act of intentionally debasing the quality of food offered for sale.
Moulds: filamentous fungi which are important group of microflora of fruits and fruit products.
Processing: changing plants or animals into what we recognize and buy as food.
Spoilage: any visible or invisible change which can makes food or product derived from food unacceptable for human consumption.
Yeasts: unicellular fungi which normally reproduce by budding.

4.6 References

Banti, M (2020). Food Adulteration and Some Methods of Detection, Review. *International Journal of Research Studies in Science, Engineering and Technology*, 7(4):9-19.

4.7 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercise

3. The four ways of adulteration:

- Addition of extraneous matter, e.g. addition of sand to food grains and water to milk
- Mixing inferior quality material with a superior one, e.g. mixing used/spent tea leaves with fresh tea leaves
- The use of prohibited dyes and preservatives, e.g. coloring of spices
- Extraction of valuable ingredients, e.g. abstraction of fat from milk or oils from spices.

4. Flour, pulse, oil, fruit, vegetable, milk, sweet, spices, tea, coffee, honey, bakery item, chocolate, fruit juice, etc.

MODULE 6

UNIT 1 COMPOSITION AND STRUCTURE OF NIGERIA/WEST AFRICA FOOD

CONTENTS

1.1 INTRODUCTION

Foods commonly consumed by humans include: Cereals, and Cereal Products, Starchy roots and tubers, Legumes (Pulses), leafy vegetables, fruits, nuts and seeds, sugars, syrups, sweets and preserves, meat, poultry and other meat products, sea food, shell fish, eggs, and roe, milk, cream and cheese, fats and oils, herbs and spices, non-alcoholic and non-dairy beverages, alcoholic beverages, dietetic preparations, and others like salt, maggi cubes, iru, vinegar and fermented condiments.

This unit will enable the student to gain an insight into quantity and quality of the food you eat. You will be able to identify many of the major and minor chemical components in your food. It will be possible, by the end of the unit, to determine whether your diet fulfills the natural requirements to keep you healthy or not.

1.2 Learning Outcomes

By the end of this unit, you will be able to:

- discuss the nutrient composition of some Nigerian/African foods
- Write the classes foods according to their composition
- Analyse the composition of foods to the use of therapeutic diets.

1.3 Nutrient Composition of Some Nigerian Foods

1.3.1 Moisture Content

The Moisture content of Nigerian/African foods may fluctuate greatly with season, length of storage, temperature of storage, composition of the foods, etc. In calculating energy values of food, moisture contents must be accurately determined and subtracted from whole to estimate total dry matter. Water in itself does not provide either nutrients or energy.

1.3.2 Food Energy

The energy values of the foods represent the available energy calculated by the specific factors for protein, fat, and total carbohydrate by difference, which is obtained by subtracting the sum of the figures for moisture, protein, fat, and ash from 100. These factors have taken into account the losses in digestion and metabolism.

1.3.3 Protein

The values for protein were computed from the nitrogen content as determined by the Kjeldahl method, multiplied by a conversion factor. From the fact that most proteins contain approximately 16 percent nitrogen, protein contents were calculated with the factor 6.25 for the conversion of nitrogen to protein.

1.3.4 Vitamins

Apart from the macro nutrients of Carbohydrate, Proteins and Fats, Foods supply micronutrients in form of Vitamins and Minerals.

The Vitamins are divided into two major groups: (a) Fat Soluble and (b) Water Soluble. Ascorbic acid or Vitamin C belongs to both groups.

The Fat Soluble Vitamins are Vitamin A, Vitamin D, Vitamin E and Vitamin K

The Water Soluble Vitamins are Thiamine (B_1), Riboflavin (B_2), Pyridoxal Phosphate (B_6), Niacin, Pantothenic Acid, Folic Acid, and Vitamin B_{12}. Vitamin C is both water soluble and fat soluble because it is retained in the blood plasma where its level can be estimated.

1.3.5 The Minerals

The micronutrients known as minerals also occur in foods in minute amounts but are very essential for body metabolisms. They act as catalysts and coenzymes to facilitate body reactions in intermediary metabolisms. Examples of minerals include Sodium (Na); present in abundance in common salt (Nacl.); Potassium (K); Calcium (Ca); Iron (Fe); Phosphorus (P); Magnesium (Mg).; Iodine (12); Zinc (Zn); Cobalt (Co); and Sulphur (S).

1.3.6 Changing Food Habits and Related Problems

Traditional food habits in themselves have rarely been the cause of malnutrition and nutritional-deficiency diseases. The usual cause of such problems has been a simple lack of food, whether because of environmental conditions or of poverty. The poor in any society may be forced to consume less food or a more limited variety of foods than they require. If the staple is protein-low (e.g. cassava or plantain based), the poor who cannot afford legumes or animal products to supplement the staple may suffer from kwashiorkor; if the staple is maize, pellagra may become prevalent if other foods are not consumed along with the maize. Advances in agricultural and food processing techniques have led to increased food supply and a nutritionally enriched diet. Nevertheless, modernization and westernization of traditional food habits have also had their deleterious effects. For example, the wide acceptance of refined rice (like Uncle Bens, Arosso, Tomato etc) at the expense of locally parboiled rice (like Ofada, Abakaliki, Ekiti etc) at the turn of the 20th century caused a scourge of beriberi (a niacin-deficiency disease) in many developing countries, resulting in thousands of deaths. The substitution of bottle-feeding for breast-feeding among poor families has also been implicated in a great deal of malnutrition and diarrheal diseases in Nigeria.

Changing food habits have had harmful effects in the affluent developed nations, as well. The proportion of energy obtained from carbohydrates has dropped significantly (often ranging from 35 to 50%), while that obtained from fats and protein – particularly animal protein is on a steady rise. The increased intake of saturated fat and cholesterol, coupled with inadequate exercises has been related to an increased prevalence of cardiovascular disease globally. In the developed countries, about 40% of the calories supplied by their diets are derived from fat and about 20% from sugar. There has also been notable increase in fat and sugar intake especially in developing countries. However, fat and sugar crowd out other foods. In a population that is largely sedentary, this tends to lead to obesity and deficiencies in iron, calcium, complex carbohydrates and fibres which can in turn, cause a host of health problems.

Self- Assessment Exercises 1

1. List the fat-soluble vitamins
2. What is the major function of micronutrient in the body.

1.5 Food Composition

1.5.1 Proteins

Proteins are large molecules with widely varied properties and many different functions. Proteins consist of amino acids linked together by peptide bonds. Haemoglobin - a red blood cell protein is involved in the transportion of oxygen. Enzymes are proteins that catalyse the chemical reactions of cells. Collagen is a major structural protein in bones, tendons and skin. Antibodies, which are critical components of the immune system, and crystallins, found in the lens of the eye, are proteins. Some hormones are proteins. The main functions of protein are: to build body tissue, regulate functions such as muscle contraction and blood pressure, synthesize enzymes and some hormones (such as insulin) and other complex substances that govern body processes.

Structure and Composition of Proteins

The name of the acids comes from the stem word "amine" meaning "derived from ammonia." There are about 20 common amino acids in most proteins. The amino acids join together in long chains, the amino group (- NH-) of one amino acid link with the carboxyl group (-COO-) of another. The linkage is known as a peptide bond (-$COONH_2$) and a chain of amino acids is known as a polypeptide. The amino acids differ in structure and properties as a result of diiference in the content and size of side chain; each has an amino group, a carboxylic acid group and an alkyl side chain (-R). Some amino acid side chain are composed of only carbon and hydrogen atoms and are hydrophobic (water hating) and some contain oxygen and nitrogen atoms and are hydrophilic (water loving); some ionise and have positive or negative electrostatic charges. Each protein has a specific number and sequence of amino acids, where peptide bonds connect the amino group of one to the carboxyl group of the next. The resulting linear sequences give each protein a specific size, a unique three-dimensional structure and in one way or another, account for its properties.

Protein and Nutrition

Plants, bacteria and most other microorganisms synthesize all of the amino acids required for protein synthesis but humans and most other animals, cannot synthesise all of the amino acids and must obtain some of them from their diet. Eight of the 20 amino acids that make up protein, are considered essential because the body cannot synthesise them, but must be supplied ready-made in foods. When any of the essential amino acids is lacking, the remaining ones are converted into energy-yielding compounds, resulting in the excretion of its nitrogen. When excess protein is eaten, which is often the case in countries with heavy meat diets, the extra protein is similarly broken down into energy-yielding compounds. Because protein is by far scarcer than carbohydrates and yields the same 4 calories per gram, the eating of meat beyond the tissue-building demands of the body becomes a wasteful way of procuring energy. Foods from animal sources contain complete proteins because they include all the essential amino acids. In most diets, a combination of plant and animal protein is recommended 0.8 grams per kg of body weight is considered a safe daily allowance for normal adults.

Increased risks of gout, certain cancers and heart disease have been correlated with high protein diets. Kwashiorkor, a protein-deficiency disease that primarily affects children 1 to 4 years old who are weaned on starchy foods, is still endemic to parts of Africa, Asia, and South America.

1.5.2 Fats

Fats or lipids are a family of chemical compounds stored by plants and animals as a source of energy. In most animals, fats are stored in special cells that tend to form pads of tissue under the skin and around certain organs and joints, the locations depending on the species. Stored fat, or adipose tissue, serves as a fuel reserve for metabolism. Fat protects the body from shocks, joints and provides insulation. In plants, fats in the form of oil are found in the stems, seeds and fruit.

Fat is a concentrated source of energy and produce more than twice the energy produced by equal amounts of carbohydrates and proteins. Being a compact fuel, fat is efficiently stored in the body for later use when carbohydrates are in short supply. Animals obviously need stored fat to tide them over dry or cold seasons, as do humans during times of scarce food supply. All fats are made up of units of glycerol and fatty acids and the nature of fatty acids eaten can affect a person's health. Saturated fatty acids found in butter, milk and other animal products can raise the level of cholesterol in the blood, thus leading to arteriosclerosis but unsaturated fats found in vegetable oils can reduce high levels of blood cholesterol.

The body's adipose tissue is in a constant state of build-up and breakdown, thus ensuring a continual supply of fatty acids. Fatty acids containing as many hydrogen atoms as possible on the carbon chain are called saturated fatty acids and are derived mostly from animal sources. Unsaturated fatty acids are those that have some of the hydrogen atoms missing; this group includes monounsaturated fatty acids, which have a single pair of hydrogen missing, and polyunsaturated fatty acids (found mostly in seed oils), which have more than one pair missing. Saturated fats in the bloodstream have been found to raise the level of cholesterol, and polyunsaturated fat tends to lower it. Saturated fats are generally solid at room temperature; polyunsaturated fats are liquid.

The predominant substances in fats and oils are triglycerides, chemical compounds containing any three fatty acids combined with a molecule of glycerol. The fatty acids consist of a chain of carbon atoms with a carboxylic acid group (-COOH) at one end. The number of carbon atoms ranges from four to more than 22, but the most common chain length is 16 or 18. Because they are synthesized in the body from two-carbon units (acetyl coenzyme A), chain lengths are nearly always even numbers. Butyric acid is an example of a saturated fatty acid.

Fats with a high percentage of saturated fatty acids tend to be solid at room temperature; e.g. butter and lard. Those with a high percentage of unsaturated fatty acids are usually liquid oils; e.g. sunflower, safflower and corn oils. In the shorthand notation for fatty acids, the number to the left of the colon is the number of carbon atoms, while the number to the right of the colon represents the number of double bonds; e.g. 4:0 has four carbon atoms and no double bonds (i.e. saturated). This is the shorthand notation for butyric acid.

A small group of fatty acids are essential in the diet. They occur in body structures, especially the different membranes inside and around cells, and cannot be synthesized in the body from other fats. Linoleic acid (18:2) is the most important of these fatty acids because it is convertible to the other essential fatty acids. Linoleic acid has two double bonds and is a polyunsaturated fatty acid. Linoleic acid is an essential fatty acid which tends to lower the plasma cholesterol. Linoleic acid occurs in moderate to high proportions in many of the seed oils; e.g. corn, sunflower, cottonseed and safflower oils. Edible fats and oils contain smaller amounts of other lipids as well as triglycerides.

1.5.3 Carbohydrates

Carbohydrates (cellulose, starches, sugars and many other compounds), are the most abundant single class of organic substances found in nature. They are formed in green plants by a process known as photosynthesis, in which energy derived from sunlight is used for the assimilation of carbon dioxide from the air. The most common naturally occurring sugars are the aldohexoses, which have six carbon atoms and four asymmetric centres. Aldohexoses include glucose, mannose, galactose and the fruit sugar fructose. The aldopentose sugars ribose and deoxyribose (having 5 carbon atoms) are important constituents of nucleic acids.

Disaccharides and polysaccharides are formed from two or more monosaccharides joined by chemical bonds. Glucose linked to fructose, forms the disaccharide sucrose (cane sugar); glucose linked to galactose forms the disaccharide lactose (milk sugar); glucose linked to glucose forms the disaccharide maltose. Starch, glycogen and cellulose are all chains of glucose units, differing only in their modes of bonding and degree of chain branching. Some biologically important sugar derivatives are sugar alcohols, sugar acids, deoxy sugars, amino sugars, sugar phosphates, muramic, and neuraminic acids. Plants store starch in roots, tubers and leafy parts mainly during photosynthetic activity; some plants, such as sugar beets and sugarcane, also store sucrose.

Carbohydrates function as the main structural elements and storage products of energy in plants. The principal forms are starch in plants and glycogen in animal tissues. These are polymers of glucose; they are deposited in cells in the form of granules when a surplus of glucose is available. The polymers are broken down to release energy durin metabplism.

Carbohydrates and Nutrition

Carbohydrates are the most abundant food sources of energy and occur in the form of starches and sugars. Starches are found mainly in grains, legumes and pulses, roots and tubers and some rhizomes, while sugars are found in plants and fruits. The carbohydrates containing the most nutrients are the complex carbohydrates, such as unrefined grains, tubers, vegetables and fruits, which also provide protein, vitamins, minerals and fats. Other beneficial sources are foods made from refined sugar, such as confectionery and soft drinks, which are high in calories but low in nutrients and fill the body with what nutritionists call empty calories.

A large part of the human diet consists of carbohydrates in the form of starch and sucrose which must first be broken down to their component sugars by digestive enzymes before absorption into the bloodstream. In humans cells use carbohydrates in the form of glucose - the body's main fuel. After absorption from the small intestine, glucose is processed in the liver, which stores some as glycogen and passes the rest into the bloodstream. In combination with fatty acids, glucose forms triglycerides – fat compounds that can easily be broken down into combustible ketones. Glucose and triglycerides are carried by the bloodstream to the muscles and organs to be oxidised. Excess quantities are stored as fat in the adipose and other tissues for later use.

Self- Assessment Exercises 2

1. What protein-deficiency disease primarily affects children 1 to 4 years old weaned o starchy foods.
2. What are the principal forms of Carbohyrates in plants and animal tissues?

1.6 Summary

Food is composed of major nutrients such as proteins, Fats and Carbohydrates. It also consists of minor but essential nutrients such as vitamins and minerals. Cereals, roots and tubers supply energy and vitamin B complex, legumes and leafy vegetables supply proteins and carotenoids or pro- vitamin A, while meat, fish and eggs supply proteins. Animal fats contain mainly saturated fatty acids, whereas vegetable oils contain poly-unsaturated fatty acids which are essential to humans.

Food compositions differs depending on the group that it belongs to: Cereals include Rice, Corn, Millet, Sorghum which supply fibre and low tryptophan needed for body build-up of Niacin. Polished rice is also low in thiamine. Legumes, Meat, and Milk supply high proteins but also legumes contain anti-nutrients. Fruits and vegetables contain 70%

water but supply high vitamin C, Milk and milk products are rich in proteins

1.7 References/Further Readings

Walker, A.F (1990). Applied Human Nutrition. Aspen Publishers. 300 pages.

Bubel, M., Bubel, N and Art, P. (1991). Root Cellaring: Natural Cold Storage of Fruits and Vegetables. 2nd ed.

Coxe, A. H and Coxe, A. H (1997). The Great Book of Sausages. Overlook, 1992, 1997. Recipes, Instructions for Making 45 Varieties, and the History and Ingredients of 600 Types of Sausages.

Belitz, H.D., Grosch, W., Schieberle, P and M.M. Burghaghen, M.M (2004). Food Chemistry. Springer, 1071 pages

Hutkins, R (2006). Microbiology and Technology of Fermented Foods – A Modern Approach. Blackwell Publishing Professional, 488 pages

International Commission for Microbiological Specifications of Foods (ICMSF) (1996). Microorganisms in Foods - Characteristics of Microbial Pathogens – Springer. 1996. 524 pages

Marriot, N.G. and Gravani, R (2006). Principles of Food Sanitation, 5th Edition. Springer, 413 pages

Satin, M. (1996). Food Irradiation: A Guidebook. 2nd ed. Technomic. Overview of this Controversial Preservation Method.

Satin, Morton. The Food Alert!: The Ultimate Sourcebook for Food Safety. Facts on File, 1999.

1.8 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

5. **The Water Soluble Vitamins are** Thiamine (B_1), Riboflavin (B_2), Pyridoxal Phosphate (B_6), Niacin, Pantothenic Acid, Folic Acid, and Vitamin B_{12}.
6. They act as catalysts and coenzymes to facilitate body reactions in intermediary metabolisms.

Answers to Self-Assessment Exercises 2

1. Kwashiorkor
2. The principal forms are starch in plants and glycogen in animal tissues.

UNIT 2 FACTORS CONTRIBUTING TO TEXTURE, COLOUR, AROMA AND FLAVOUR OF FOOD, COST

2.1 Introduction

Foods undergo undesirable changes in the physical and chemical characteristics of food ultimately leading to spoilage of food. In general, food spoilage is a state in which food is deprived of its good or effective qualities. Spoilage of food refers to the undesirable alterations in foods or the food undergoes some physiological, chemical and biological changes, which renders it inedible or hazardous to eat. In extreme cases, the food becomes totally unpalatable and unfit for human consumption. Hence, it is essential to process or preserve foods after it is harvested or slaughtered to combat the problem of food spoilage.

Undesirable Changes in Food due to Spoilage

Food deterioration is manifested by the reduction in aroma, flavour, textural and nutritional values of foods. Different types of undesirable changes which occur due to spoilage in food are listed as follows:

i. **Change in colour:** The fruits like bananas and apples turn black after storing for a long period of time and reduce the acceptability of food.
ii. **Change in smell:** Rancid smell of spoiled oils and fats, bitter smell of curd or sour smell of starchy food.
iii. **Change in consistency:** Splitting of milk, curdling of milk, stickiness and undesirable viscosity in spoiled cooked curries and vegetables.
iv. **Change in texture:** Some vegetables like potato, brinjal and carrot undergo too much softening leading to rotting.
v. **Change due to mechanical damage:** Mechanical damages such as eggs with broken shells, mechanical spoilage of fruits and vegetables during transportation also constitute food spoilage.

2.2 Learning Outcomes

By the end of this unit, you will be able to:

- Discuss the factors that affect the texture and colour of foods
- Analyse the factors that affect the aroma and flavour of foods
- Discuss the factors that affect the cost of foods

2.3 Factors affecting the food quality

2.3.1 Factors that affect the texture and colour of foods

Texture

Textural parameters of fruits and vegetables are perceived with the sense of touch, either when the product is picked up by hand or placed in the mouth and chewed. In contrast to flavor attributes, these characteristics are fairly easily measured using instrumental methods. Most plant materials contain a significant amount of water and other liquid-soluble materials surrounded by a semi-permeable membrane and cell wall. The texture of fruits and vegetables is derived from their turgor pressure, and the composition of individual plant cell walls and the middle lamella "glue" that holds individual cells together. Cell walls are composed of cellulose, hemicellulose, pectic substances, proteins, and in the case of vegetables, lignin. Tomatoes are an example of a fruit vegetable that is approximately 93–95% water and 5–7% total solids, the latter comprised of roughly 80–90% soluble and 10–20% insoluble solids. The greatest contributor to the texture of tomato products are the insoluble solids, which are derived from cell walls. The three-dimensional network of plant cell walls is still unresolved, but is a topic of great interest to scientists in that to a large degree it dictates the perception of consistency, smoothness, juiciness etc. in fruit and vegetable tissues. The textural properties of a food are the "group of physical characteristics that arise from the structural elements of the food, sensed by the feeling of touch, are related to the deformation, disintegration and flow of the food under a force, and are measured objectively by functions of mass, time, and distance."

The terms texture, rheology, consistenc
y, and viscosity are often used interchangeably, despite the fact that they describe properties that are somewhat different. In practice the term texture is used primarily with reference to solid or semi-solid foods; however, most fruits and vegetables are viscoelastic, which imply that they exhibit combined properties of ideal liquids, which demonstrate only viscosity (flow), and ideal solids, which exhibit only elasticity (deformation).

Colour

Colour is derived from the natural pigments in fruits and vegetables, many of which change as the plant proceeds through maturation and ripening. The primary pigments imparting colour quality are the fat

soluble chlorophylls (green) and carotenoids (yellow, orange, and red) and the water soluble anthocyanins (red, blue), flavonoids (yellow), and betalains (red). In addition, enzymatic and non-enzymatic browning reactions may result in the formation of water soluble brown, gray, and black colored pigments. The enzymes involved in browning reactions include polyphenol oxidase, which catalyzes the oxidation of polyphenolic compounds, and phenylalanine ammonia lyase, which catalyzes the synthesis of precursors to phenolic substrates. The chlorophylls are sensitive to heat and acid, but stable to alkali whereas their counterpart carotenoids are sensitive to light and oxidation but relatively stable to heat. Carotenoids may be bleached by an enzyme called lipoxygenase, which catalyzes the oxidation of lipid compounds. Anthocyanins are sensitive to both pH and heat, while the flavonoids are sensitive to oxidation but relatively stable to heat. Betalains are heat sensitive as well. The appearance of food is determined by physical factors including the size, the shape, the wholeness, the presence of defects (blemishes, bruises, spots, etc.), finish or gloss, and consistency. Size and shape may be influenced by cultivar, maturity, production inputs, and the growing environment. It is important for fruits and vegetables to be of uniform size and characteristic shape. Some consumers associate larger size with higher quality. The wholeness and absence of defects will be affected by exposure to disease and insects during the growing period and the harvest and postharvest handling operations. Mechanical harvesting, for example, may incur more bruises and cracks in fruits and vegetables than hand harvesting. Fruit and vegetable gloss are related to the ability of a surface to reflect light and freshly harvested products are often more glossy. Gloss is affected by moisture content, wax deposition on the surface, and handling practices postharvest. Consistency or smoothness may be used as an appearance term, but is typically applied to semi-solid products, where it indicates the product thickness.
Five functions that should be considered in understanding human reactions to color in foods are listed below:

- **Perception**. Food selection or judgment of food quality would be extremely difficult if colour discrimination were removed, even though size, texture, shape, and other cues were left intact.
- **Motivation**. Food colour and the colour of the environment in which the food is seen can significantly increase or decrease our desire or appetite for it.
- **Emotion**. Liking or disliking a food is conditioned by its colour; attractive foods are sought out as pleasure-giving, while unattractive foods are avoided.
- **Learning**. By the process of experience, we learn what colour to expect and consider “natural,” and we predict rather precisely

what properties a food or beverage will have from our memory of similar materials.

• **Thinking**. Our reaction to unusual properties or to new foods can be changed if they are explained to us.

Obviously, far too little is known about the significance of colour perception in food acceptance. Observers do associate certain colours with acceptance, indifference, or rejection. Coloured lights are used to mask colour differences and reduce some influence of colour on sensory evaluation, but the psychological effect of coloured lights has not been adequately measured. These effects may be direct, on the appeal of the food as a whole, or indirect, in influencing odor, taste, or texture thresholds.

2.3.2 Factors that affect the aroma and flavour of foods

Flavour, Aroma and Taste: Flavor has been defined as: A mingled but unitary experience which includes sensations of taste, smell, and pressure, and often cutaneous sensations such as warmth, colour, or mild pain. Flavour is typically described by aroma (odour) and taste. Aroma compounds are volatile - they are perceived primarily with the nose, while taste receptors exist in the mouth (Tongue) and are impacted when the food is chewed. While colour and appearance may be the initial quality attributes that attract us to a fruit or vegetable product, the flavour may have the largest impact on acceptability and desire to consume it again. Taste has been divided into five primary tastes - sweet, sour, salty, bitter, and umami. Umami can be described as a taste associated with salts of amino acids and nucleotides. Odours are much more diverse and difficult to classify, but an attempt includes the following - spicy, flowery, fruity, resinous or balsamic, burnt, and foul. It is possible to classify vegetables into two major groups, depending on their flavour characteristics. The first group of fruits and vegetables has a strong flavour that can be attributed to a single compound or group of related compounds. Bananas with isoamylacetate, onions with characteristic sulfide compounds, and celery, with distinctive phthalides are examples of this group. The second group of fruits and vegetables includes those whose flavour is determined by a number of volatiles, none of which conveys the specific characteristic aroma. Examples in this group include snap beans, muskmelons, and tomatoes. In the evaluation of fruit and vegetable flavour, it is important to consider "off-flavours" as well as desirable ones. These off-flavours may be produced through the action of enzymes such as lipoxygenase or peroxidase, which form reactive free radicals and hydroperoxides that may catalyze the oxidation of lipid compounds. When these reactions occur, the result may be the development of undesirable flavours described as rancid, cardboard, oxidized, or wet dog. However, there are instances of enzyme-catalyzed reactions that result in desirable flavours. For example, hydroperoxide lyase catalyzes the production of a typical tomato flavours.

2.3.3 Factors that affect the cost of foods

i. Cost of Production: Cost of production is the main component of price as no company or producer can sell its products or services at less than the cost of production. It is necessary to compile data relating to the cost of production and keep that in mind.

ii. Demand for product: intensive study of demand for product and services in the market be undertaken before price fixation. If the demand is relatively more than supply, higher price can be fixed.

iii. Government regulation: if the price of the commodity and services is to be fixed as per the regulation of the government, it should also be borne in mind.

iv. Marketing Method Used: Costs of foods are influenced by the method used by the producer for the sale of the goods. If customers are to be provided with "after sale serice" facility, then the expenses are added to the price.

v. Nature of the food.

Self-Assessment Exercises 1

1. Describe the undesirable changes that occur due to spoilage in foods.
2. What canyou use to describe the flavour of food?

2.4 Summary

The color, flavour, texture, and cost of fruits and vegetable products are factors critical to consumer acceptance and the success of these products. In this unit, desirable and undesirable quality attributes of fresh-cut fruit and vegetable products were discussed. Both instrumental and sensory measurements for determining this critical quality attributes, the advantages and disadvantages of sensory and instrumental quality measurements were also discussed.

2.5 References/Further Readings

Barrett, D.M., Beaulieu, J.C. and Shewfelt, R (2010). Color, Flavor, Texture, and Nutritional Quality of Fresh-Cut Fruits and Vegetables: Desirable Levels, Instrumental and Sensory Measurement, and the Effects of Processing. *Critical Reviews in Food Science and Nutrition*, 50:369–389. DOI: 10.1080/10408391003626322

Molnar, P.J (2011). Food Quality and Standards, *Food Quality Indices, (2).*

Kader, A. A. (2002). Postharvest Technology of Horticultural Crops, (ed.) University of California, ANR Publication 3311. 3rd edition. 535

Marrero, A. and Kader, A. A. (2006). Optimal temperature and modified atmosphere for keeping quality of fresh-cut pineapples. *Postharvest Biol and Technol*. 30:163–168

2.6 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. The undesirable changes which occur due to spoilage in food are listed as follows:

i. Change in colour: The fruits like bananas and apples turn black after storing for a long period of time and reduce the acceptability of food.

ii. Change in smell: Rancid smell of spoiled oils and fats, bitter smell of curd or sour smell of starchy food.

iii. Change in consistency: Splitting of milk, curdling of milk, stickiness and undesirable viscosity in spoiled cooked curries and vegetables.

iv. Change in texture: Some vegetables like potato, brinjal and carrot undergo too much softening leading to rotting.

v. Change due to mechanical damage: Mechanical damages such as eggs with broken shells, mechanical spoilage of fruits and vegetables during transportation also constitute food spoilage.

2. Flavour is typically described by aroma (odour) and taste.

UNIT 3 TRADITIONAL AND ETHNIC INFLUENCES OF FOOD PREPARATION AND CONSUMPTION PATTERN.

3.1 Introduction

Tradition, Cultural beliefs and ethnicity influence the consumption and the preparation of certain foods especially in special times in different cultures. Religion and traditions in different cultures lead to restrictions of some food from the diet. Culture and religion influence food consumption patterns.

Although food consumption is mainly considered as an intake of nourishment in order to survive, it is also accepted as collecting information about the backgrounds, history and culture of different countries and developing social practices in which people relating other people in social, cultural and political terms. All human beings eat to survive but they also eat and share food to express gratitude and thankfulness, for a sense of belonging, as part of family and cultural traditions, and for self-realization. The meal times and components of a meal vary across cultures. Culture, religion and traditional knowledge affect food, food consumption, food preparation, and food preferences.

Food, being one of the components of culture, food cultures or foodways reveals how a certain group of people express, create, maintain, and reinforce their cultural, ethnic, and individual identities through symbolic expressions. Food culture tells important historical events, legends, folklore and traditions. Consuming traditional foods symbolically connects and maintains an ethnic identity. As communities shape cultural identity, cultural identity also shapes food culture-foodways. Consequently, it can be said that the demand for certain foods and the meaning attached to specific foods, the styles of preparation and serving, and eating practices are shaped by food culture.

Environmental, social, economic, and individual factors influence food consumption pattern. Ecological factors include seasonal variations, land-use diversity, climate, and the environment; social factors include those related to an aging population, urbanization, cultural diversity, and festivals. The economic factors include income, development, urban–rural economic differences, price, and markets. The national income level, personal social status, affordability, health concepts, purchase preference, perceived value, and genetic characteristics could influence dietary structures.

3.2 Learning Outcomes

By the end of this unint, you will be able to:

- Discuss how tradition and ethnicity influence food preparation and consumption pattern
- Discuss factors that affect food consumption pattern
- Analyse the effect of food consumption pattern on rural development

3.3.1 Relationship between Culture/tradition, ethnicity and Food

Beliefs, values, and attitudes which are practiced and acknowledged by the members of a group or a community, defines the concept of culture. “Culture means the whole complex of traditional behaviour which has been developed by the human race and is successively learned by each generation”. Culture is a learned concept it is not inherited and it is linked with the social structure and in this sense, the individuals of a community are the carriers of culture. As culture is learned, it can be said that the information is spread orally from generation to generation and it can be seen and observed and practiced in the form of stories, cultural values, rituals and beliefs. Taking all these into consideration, it is possible to say that food can be considered as one of the most easily reached point of entry into a community to understand and evaluate cultures, subcultures and traditions as food is universal but different cultural groups and different societies have different choices of food due to tradition and ethnic behaviours. “Eating is a daily reaffirmation of one’s cultural identity”. Therefore, it can be stated that the food choices, food culture and food consumption habits can reveal an insight of a culture.

Food Consumption Patterns

The food consumption pattern of countries constantly changes with the continuous growth in income and rapid urbanization and the factors influencing it are also changing. In addition to the changing food consumption pattern, with increasing carbon dioxide emissions and the resultant global climate change, nutrient content and crop yields are predicted to decrease, affecting food security. Household food security among smallholder farmers is sensitive to variable and changing climates, and in some rural and underdeveloped regions, particularly those in remote and high-altitude localities, the impact of climate change on food consumption safety needs close attention. To counteract and prevent the adverse effects of possible nutrient deficiency or a declining trend in local crops, adjustments in dietary structure could be an effective way to balance nutrient levels in the human body.

The food consumption patterns of subjects can be divided into three modes:

Mode one: here the consumption frequency of staple food, fruits, and vegetables is relatively high, and the structure diversified.

Mode two: in this mode, there is relatively high consumption frequency of staple food, meat, and milk, and the structure is less complicated than mode 1.

Mode three: here there is a relatively high consumption frequency of staple food, and the dietary structure was relatively singular.

3.3.2 How culture influence food preferences

Food preferences are mostly mediated by exposure and between exposure and liking, most of the time there is a positive relationship but the main factor of the exposed foods depends on the culture. Most people associate some foods with family, memories of special days and these can also be considered as comfort foods in case of stress and depression. From research, flavour conditioning also plays an important role in food choices. This flavour conditioning can be influenced by direct or indirect social factors and family food rules in childhood. For example, some food put on the table by the mother on special days and shared communally can influence food preferences. Thus it can be stated that through family food culture and traditions are transferred to the next generations. In almost every culture some foods symbolize and are related with certain days, traditions and sharing of food is the main construct of social connections, ties and values. This can be seen mostly in the case of traditional meals on celebrations and some religious holiday meals where people interact with rituals.

3.3.3 Factors Affecting Food Consumption Patterns

Food consumption patterns can be defined as the recognizable ways of eating foods. Rural dwellers tend to adhere to their old eating patterns rather than venturing to seek new and more proper eating habits. In order to maintain healthful diets, a variety and balance of foods from all food groups and moderate consumption of all food items is very important. Variety in the diet implied choosing a number of different foods within any given food group, rather than eating the "same old thing" day after day.

Food consumption pattern has been observed to be influenced by socio-economic factors including sex, income, occupation, type of house and source of cooking energy. Also, food consumption patterns of the mother prior to conception and during pregnancy and lactation affects the reproductive cycle and health of the newborn infant. A mother with poor food consumption patterns have the risk of delivering a baby that is physically and mentally handicapped. Many complex interacting systems affect man's food consumption patterns and his consequent state of health. The natural environment (climate, topography, soil conditions etc) determines what food can be produced while the man made environment (technological developments for processing, storing and distribution of food) affects what food will be made available for consumption.

The behavioural environment (religion, ethnicity, economics, cultural/traditions) determines what specific foods will be selected from the variety that are available before they are acceptable for consumption in a particular group to which the individual belongs. Adequate food consumption pattern play an important role in rural development activities and ensures their capacity to embark on livelihood activities that is sustainable.

The growing processing of foodstuffs itself has an increasing influence on food consumption patterns. Vegetable oils, for instance, are important sources of essential fatty acids, but are as such not readily useable as ingredients for many sophisticated food products. Hydrogenation makes possible the conversion of fluid oils into spreadable margarine but the same process turns valuable unsaturated fatty acids into non-essential fats and into potentially harmful trans-fatty acids. Likewise, the almost universal shift to refined grain flour has a direct impact on the nutrient intakes particularly where wheat and maize are staple foods. Modern milling procedures produce refined flour which has better digestibility but destroys its texture, structure and valuable dietary fibre and decimates their minerals and vitamins. Also, producing white flour makes little sense from a nutritional perspective (its production entails high losses of total protein as well as lowering the quality), but it makes baking a lot easier.

3.3.4 Food Consumption Patterns and Rural Development

Proper and adequate food consumption patterns is the instrument for achieving other rural developmental goals, especially those connected to reduction in child mortality and improvements in maternal health, primary education enrolment and achievement, gender equity and the capacity to resist diseases. In order to be healthy and active, rural dwellers need to have food in adequate quantity, quality and variety in order to meet their energy and nutrient requirements. Inadequate nutrition prevents children from developing their potentials while adults will experience difficulty in maintaining or expanding theirs. A nutritious adequate diet must include all the important nutrients. Certain cultures and tribes prohibit the consumption of certain food items of high nutritive value on an account of ethnic or religious beliefs and taboos. Most of these beliefs have no scientific basis and they tend to deprive people from eating nutritious and balanced diets. Rural dwellers are always victims of these taboos due to their conservative nature. This shows that food is vital for body growth and development, work, survival and reproduction. Therefore poor food consumption patterns will surely affect the nutritional and health status, the capacity of the rural dwellers to produce enough for sustainable income and food security.

Self- Assessment Exercises 1

1. What are the economic factors that influence food consumption pattern?
2. State the effect of proper and adequate food consumption pattern on rural development.

3.4 Summary

.There is both individual and regional differences in food preparation and consumption patterns. Individual factors such as age, education, family member composition, and regional factors, namely time from the township to the region, cultivation area, and meat production, might have a considerable influence on Nigerian food consumption. attention.

3.5 References/Further Readings

ACC/SCN (2004). Fifth Report on the World Nutrition Situation. UN Standing Committee on Nutrition General, in collaboration with the International Food Policy research Institute, Washington. P9

Ezzati, M. Hoorn SV Rodgers A (2003); Comparative Risk Assessment Collaborating Group Estimates of global and regional potential health gains from reducing multiple major risk factors. The Laucet, 362 (9380); 271-80.

FAO, (2001); Feeding minds: Fighting Hunger: A World tree from Hunger food and Agriculture Organization of the United Nations, Rome p9

Jama, P.P. (2002): A healthy diet: Journal of the American Medical Association. 283:2198, 2000.

Wright, H-Sandsims, L.S. (1981): Community Nutrition: People, Policies and Programmes Jones and Bartleft Publishers, pp 238.

Yahaya, M.K. (2000): Food and Nutrition. In Akinbile, L.A. and Odebode, S.O. (eds.) Ibadan External Studies Programme Series, pp. 11.

Ajala, C.G. and Meludu, N.T (2006). Food consumption patterns of adult rural dwellers in oluyole local government area of oyo state, Nigeria. *Journal of Agriculture and Social Research*, 6(2):32-39

Smil, V (1999). “China's great famine: 40 years later”. *British Medical Journal Volume,* 319: 1619-1621

Kong, C., Yang, L., Gong, H., Wang, L., Li, H., Li, Y., Wei, B., Nima, C., Deji, Y., Zhao, S., Guo, M., Gu, L., Yu, J., Gesang, Z and Li, R (2022). Dietary and Food Consumption Patterns and Their Associated Factors in the Tibetan Plateau Population: Results from 73 Counties with Agriculture and Animal Husbandry in Tibet, China. *Nutrients,* 2022, 14, 1955. https://doi.org/10.3390/nu14091955

3.6 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. The socio-economic factors that affect the food consumption pattern include sex, income, occupation, type of house and source of cooking energy.
2. Proper and adequate food consumption patterns is the instrument for achieving other rural developmental goals, especially those connected to reduction in child mortality and improvements in maternal health, primary education enrolment and achievement, gender equity and the capacity to resist diseases.

Unit 4 SANITATION

CONTENTS

4.1 **Introduction**

According to the World Health Organization (W.H.O), "Sanitation refers to the maintenance of hygienic conditions, through services such as garbage collection and waste disposal. Inadequate sanitation is a major cause of diseases worldwide and improving sanitation is known to have significant beneficial impact on health both in households and across communities."

There are three main types of hazards or contaminants that can cause unsafe food: Biological, chemical, and physical. Biological includes microorganisms; chemical includes cleaning solvents and pest control; and physical means hair, dirt, or other matter. Five frequently mentioned sanitation tips to prevent food borne illnesses in food service are:

1. Proper personal hygiene, including frequent hand and arm washing and covering cuts;
2. Proper cleaning and sanitizing of all food contact surfaces and utensils
3. Proper cleaning and sanitizing of food equipment
4. Good basic housekeeping and maintenance
5. Food storage for the proper time and at safe temperatures.

Proper employee education and training, as well as monitoring and recordkeeping by management of clean and sanitation tasks are also important.

The main objective of sanitation is to minimize the access of microorganisms in food from various sources at all stages of handling. Because the microbial sources and level of handling vary with each food of plant and animal origin and fabricated foods, the methods by which microorganisms contaminate foods differ. Proper sanitation helps reduce the microbial load to desired levels in further processed food. An example of this is that a low microbial level in raw milk produced through effective sanitation makes it easier to produce pasteurized milk that meets the microbial standard. Also, proper sanitation helps produce food that, when properly handled and stored, will have a long shelf life. Finally, proper sanitation helps reduce the incidence of foodborne diseases.

4.2 Learning Outcomes

By the end of this unit, you will be able to:

- Analyse Hazard analysis critical control point (HACCP)
- Discuss Personal hygiene
- Discuss Environmental hygiene
- Write the Effects of sanitation on food

4.3 Methods and agents used in food Sanitation

4.3.1 Hazard Analysis Critical Control Point (HACCP)

Hazard is a biological, chemical, or physical agent that is reasonably likely to cause illness or injury in the absence of its control. Hazard Analysis is the process of collecting and evaluating information on hazards associated with the food under consideration to decide which are significant and must be addressed in the HACCP plan. Hazard Analysis Critical Control Points (HACCP) is a system which provides the framework for monitoring the total food system, from harvesting to consumption, to reduce the risk of foodborne illness. The system is designed to identify and control potential problems before they occur. The application of HACCP is based on technical and scientific principles that assure safe food.

HACCP consists of seven steps used to monitor food as it flows through the establishment, whether it is a food processing plant or foodservice operation. The seven steps of the HACCP system address the analysis and control of biological, chemical and physical hazards.

HACCP terminology

Critical Control Point (CCP): A procedure/practice (control) in food handling/preparation that will reduce, eliminate or prevent hazards. It is a "kill" step that kills microorganisms or a control step that prevents or slows their growth.

Hazard: Unacceptable contamination, microbial growth, persistence of toxins or survival of microorganisms that are of a concern to food safety

Monitoring: Checking to determine if the criteria established by the critical control point(s) (CCP) have been achieved

Risk: Probability that a condition(s) will lead to a hazard

Severity: Seriousness of the consequences of the results of a hazard

Formal HACCP seven steps:

1. Conduct a hazardous analysis.

The purpose of a hazardous analysis is to develop a list of hazards which are likely to cause injury or illness if they are not controlled. Points to be considered in this analysis can include: skill level of employees; transport of food; serving elderly, sick, very young children, immunecompromised; volume cooling; thawing of potentially hazardous foods; high degree of food handling and contact; adequacy of preparation and holding equipment available; storage, and method of preparation. The next step is to determine if the factors may influence the likely occurrence and severity of the hazard being controlled. Finally, the hazards associated with each step in the flow of food should be listed along with the measures necessary to control the hazard.

2. Determine Critical Control Points (CCP's)

A critical control point is any step in which hazards can be prevented, eliminated or reduced to acceptable levels. CCP's are usually practices/procedures which, when not done correctly, are the leading causes of foodborne illness outbreaks. Examples of critical control points include cooking, cooling, re-heating, holding.

3. Establish Critical Limits

A critical limit ensures that a biological, chemical or physical hazard is controlled by a CCP. Each CCP should have at least one critical limit. Critical limits must be something that can be monitored by measurement or observation. They must be scientifically and/or regulatory based. Examples include temperature, time, pH, water activity or available chlorine.

4. Establish Monitoring Procedures

The monitoring system should be easy to use and meet the needs of the food establishment, as well as the regulatory authority. It is important that the job of monitoring be assigned to a specific individual and they be trained on the monitoring technique.

5. Establish Corrective Actions

Corrective actions may range, for example, from "continue cooking until the established temperature is reached" to "throw out the product," depending on the severity of the situation. HACCP plans should be established in advance to include the following: who is responsible for implementing the corrective action and what corrective action was taken.

6. Establish verification procedures

Verification can be accomplished by expert advice and scientific studies and observations of the flow of food, measurements and evaluations. Another means of verification is an onsite review of the established critical limits. Each CCP will have one independent authority. This verification step provides an opportunity to make modifications to the plan if necessary.

7. Establish record-keeping and documentation procedures

Record-keeping and documentation procedures should be simple to complete and include information that illustrates that the established standards are being met. Employees need to be trained on the record-keeping procedures and why it is a critical part of their job. Examples of records include time/temperature logs, checklists, forms, flowcharts, employee training records, etc.

4.3.2 Personal Hygiene

Personal hygiene begins at home, with the essential elements for good hygiene being a clean body, clean hair and clean clothing. Hair in food can be a source of both microbiological and physical contamination. Hairnets and beard covers should be worn to assure food product integrity. Long-sleeved smocks should be worn to cover arm hair. Clean uniforms, aprons and other outer garments that are put on after the employee gets to work can help minimize contamination. While working, clothing should be kept reasonably clean and in good repair. Removal of smocks, laboratory coats or aprons should take place when leaving the work area to go to the employee break room, restroom or exiting the building. Personal items such as meals and snacks should be stored in a locker or break room area that is located away from processing areas or areas where equipment and utensils are washed.

The only jewelry allowed in a food plant is a plain wedding band and/or one small post earring in each ear. No other jewelry is to be worn because it may fall into the product, it can present a safety hazard and it cannot be adequately sanitized against bacterial transmission. It should be removed prior to entering the processing facility. Employees must wear different colored smocks when going from a raw processing part of the establishment to the cooked processing side. They should also step into a sanitizer footbath between the two processing areas to eliminate the bacteria on their shoes.

No employee who is affected with, has been exposed to, or is a carrier of a communicable disease, the flu or a respiratory problem, or any other potential source of microbiological contamination shall work in any area where there is a reasonable possibility that food or food ingredients can be contaminated. The number one symptom of a foodborne illness is diarrhoea. Other symptoms include fever, dizziness, vomiting, and sore throat with fever or jaundice. Any employee with these symptoms should not be allowed to work around food. If an employee has been diagnosed with a foodborne illness, exclude them from the establishment, and contact the local health department. The health department must be notified if the employee has been diagnosed with one of the following foodborne illnesses: *Salmonella typhi, Shigella species, shiga* toxin producing *E. coli,* or hepatitis A virus.

4.3.3 Factors to Consider during Sanitation in foods

To minimize the access of microorganisms in foods, the microbiological quality of the environment to which a food is exposed (food contact surfaces) and the ingredients added to a food should be of good microbiological quality. To achieve these goals, several factors need to be considered, which are briefly discussed here.

i. Plant Design

At the initial designing stage of a food-processing plant, an efficient sanitary program has to be integrated in order to provide maximum protection against microbial contamination of foods. This includes both the outside and the inside of the plant. Some elements to consider are specific floor plan, approved materials used in construction, adequate light, air ventilation, direction of air flow, separation of processing areas for raw and finished products, sufficient space for operation and movement, approved plumbing, water supply, sewage disposal system, waste treatment facilities, drainage, soil conditions, and the surrounding environment. Regulatory agencies have specifications for many of these requirements and can be consulted at the initial stage of planning to avoid costly modifications.

ii. Quality of Water, Ice, Brine, and Curing Solution

Water is used as an ingredient in many foods and is also used in some products after heat treatment. The microbiological quality of this water, especially if the foods are ready-to-eat types, should not only be free from pathogens but also be low (if not free) in spoilage bacteria such as *Pseudomonas spp*. This is particularly important for foods kept at low temperature for extended shelf life. The ice used for chilling unpackaged foods also should not contaminate a food with pathogenic and spoilage bacteria. Water used for chilling products, such as chicken at the final stage of processing, can be a source of cross-contamination of a large number of birds from a single bird contaminated with an enteric pathogen. Similarly, the warm water used to de-feather chicken can be a source of thermoduric bacteria. Brine and curing solutions used in products such as ham, bacon, turkey-ham, and cured beef brisket can be a source of microbial contamination. To reduce this, brine and curing solutions should be made fresh and used daily. Storing brine for extended periods before use may reduce the concentration of nitrite through formation and dissipation of nitrous oxide and may reduce shelf life of the products.

3. Quality of Air

Some food-processing operations, such as spray drying of nonfat dry milk, require large volumes of air that come into direct contact with the food. Although the air is heated, it does not kill all the microorganisms present in the dust of the air and thus can be a source of microbial contamination of foods. The installation of air inlets to obtain dry air with the least amount of dust and filtration of the air is important to reduce microbial contamination from this source.

4. Training of Personnel

A processing plant should have an active program to teach the plant personnel the importance of sanitation and personal hygiene to ensure product safety and stability. The program should not only teach how to achieve good sanitation and personal hygiene but also monitor the implementation of the program. People with an illness and infection should be kept away from handling the products.

5. Equipment

The most important microbiological criterion to be considered during the design of food processing equipment is that it should protect a food from microbial contamination. This can be achieved if the equipment does not contain dead spots where microorganisms harbour and grow or that cannot be easily and readily cleaned in place or by disassembling. Some of the equipment, such as meat grinders, choppers, or slicers and several types of conveyor systems, may not be cleaned and sanitized very effectively and therefore serve as a source of contamination to a large volume of product. This is particularly important for products that come in contact with equipment surfaces after heat treatment and before packaging.

6. Cleaning of Processing Facilities

Cleaning is used to remove visible and invisible soil and dirt from the food-processing surroundings and equipment. The nature of soil varies greatly with the type of food processed, but chemically it consists of lipids, proteins, carbohydrates, and some minerals. Although water is used for some cleaning, to increase efficiency of cleaning, chemical agents or detergents are used with water. In addition, some form of energy with the liquids, such as spraying, scrubbing, or turbulent flow, is used for better cleaning. Many types of detergents are available, and they are selected based on the need. The effectiveness of a cleaning agent to remove soil from surfaces depends on several characteristics, such as efficiency of emulsifying lipids, dissolving proteins, and solubilizing or suspending carbohydrates and minerals. Also, a detergent should be noncorrosive, safe, rinsed easily, and compatible, when required, with other chemical agents. The detergents frequently used in food processing facilities are synthetic, which can be anionic, cationic, or nonionic. Among these, anionic detergents are used with higher frequency. Examples of anionic detergents include sodium lauryl sulfate and different alkyl benzene sulfonates and alkyl sulfonates. Each molecule has a hydrophobic or lipophilic (nonpolar) segment and a hydrophilic or lipophobic (polar) segment. The ability of a detergent to remove dirt from a surface is attributed to the hydrophobic segment of a molecule. They dissolve the lipid materials of the soil on the surface by forming micelles with the polar segments protruding outside in the water. The concentration of a detergent at which micelle formation starts is called the critical micelle concentration (CMC), which varies with the detergent. The concentration of a detergent is used above its CMC level.

The frequency of cleaning depends on the products being processed and the commitment of the management to good sanitation. From a microbiological standpoint, prior microbiological evaluation of a product can give an indication about the frequency of cleaning necessary in a particular facility. Cleaning of the equipment is done either after disassembling the equipment or by the CIP system. Because of its efficiency and lower cost, CIP cleaning has become popular. The system uses detergent solutions at a high pressure. Because microorganisms can grow in some detergent solutions, they preferably should be prepared fresh (not exceeding 48 hours).

4.3.4 Sanitation of Food Processing Equipment

Efficient cleaning can remove some microorganisms along with the soil from the food contact surfaces, but cannot ensure complete removal of pathogens. To achieve this goal, food contact surfaces are subjected to sanitation after cleaning. The methods should effectively destroy pathogenic microorganisms as well as reduce total microbial load. Several physical and chemical methods are used for sanitation of food processing equipment. Physical agents used for sanitation of food processing equipment include hot water, steam, hot air, and UV irradiation. UV irradiation is used to disinfect surfaces. Hot water and steam, although less costly and efficient for destroying vegetative cells, viruses, and spores (especially steam) can be used only in a limited way. Chemical sanitizers are used more frequently than physical sanitizers. Several groups of sanitizers are approved for use in food processing plants. They vary greatly in their antimicrobial efficiency. Some of the desirable characteristics used in selecting a chemical sanitizer are effectiveness for a specific need, nontoxicity, non-corrosiveness, no effect on food quality, easy to use and rinse, stability, and cost effectiveness. Important factors for antimicrobial efficiency are exposure time, temperature, concentrations used, pH, microbial load and type, microbial attachment to surface, and water hardness. Some sanitizers, designated as detergent sanitizers, can both clean and sanitize. They can be used in a single operation instead of first using detergent to remove the soil and then using sanitizers to control microorganisms. The mechanisms of antimicrobial action and the advantages and disadvantages of some of the sanitizers used in food-processing plants are briefly below.

4.3.5 Sanitizing agents

a. Chlorine-Based Sanitizers

Some of the chlorine compounds used as sanitizers include: liquid chlorine, hypochlorites, inorganic or organic chloramines, and chlorine dioxide. Chlorine compounds are effective against vegetative cells of bacteria, yeasts and molds, spores, and viruses. Clostridial spores are more sensitive to chlorine compounds than are bacilli spores. The antimicrobial action of chlorine compounds is due to the oxidizing effect of chlorine on the –SH group in many enzymes and structural proteins.

The damage to membrane, disruption of protein synthesis, reactions with nucleic acids, and interference with metabolisms has been suggested. The germicidal action of liquid chlorine and hypochlorites is produced by hypochlorous acid (HOCl). It probably enters the cell and reacts with the –SH group of proteins. HOCl is stable at acid pH and is thus more effective; at alkaline pH, it dissociates to H+ and OCl– (hypochlorite ions), which reduces its germicidal effectiveness. They are also less effective in the presence of organic matter. Chloramines (inorganic or organic), such as Chloramine T, release chlorine slowly, but they are less active against bacterial spores and viruses. They are effective, to some extent, against vegetative cells at alkaline pH. Chlorine dioxide is more effective at alkaline pH and in the presence of organic matter. Chlorine compounds are fast acting against all types of microorganisms, less costly, and easy to use. However, they are unstable at higher temperatures and with organic matter, corrosive to metals, can oxidize food, and are less active in hard water.

b. **Iodophores**

Iodophores are prepared by combining iodine with surface-active compounds, such as alkylphenoxypolyglycol. Because of the surface-active compounds, they are relatively soluble in water. Iodophores are effective against Gram-positive and Gram-negative bacteria, bacterial spores, viruses, and fungi. Their germicidal property is attributed to elemental iodine (I_2) and hypoiodous acid, which oxidize the –SH group of proteins, including key enzymes. They are more effective at acidic pH and higher temperatures and in the presence of organic matters, they do not lose germicidal property as rapidly as chlorine does. However, their effectiveness is reduced in hard water. They are fast acting, noncorrosive, easy to use, nonirritating, and stable. Iodophores are expensive, less effective than hypochlorites against spores and viruses, can cause flavor problems in products, and react with starch.

c. Quaternary Ammonium Compounds

Quaternary ammonium compounds (QACs) can be used as detergent sanitizers because they have cleaning properties along with germicidal abilities. However, they are principally used as sanitizers. They are synthesized by reacting tertiary amines with alkyl halides or benzyl chloride.

The cationic group is hydrophobic and the anionic group is hydrophilic. QACs can act as bactericides in high concentrations and when used in solution. However, they form a film on the equipment surface, in which state are bacteriostatic. They are more effective against Gram-positive bacteria than many Gram-negative bacteria, bacterial spores, fungi, and viruses. The antimicrobial action is produced by the denaturation of microbial proteins and destabilization of membrane functions. They are more effective against microorganisms at acidic pH and higher temperature. Their effectiveness is not greatly reduced in the presence of organic matters. However, they are less effective in hard water. QACs are advantageous as sanitizers because they are highly stable, non-corrosive, non-irritating, non-toxic, show residual bacteriostatic effect, and show detergent effect. The disadvantages are high cost; low activity against many Gram-negative bacteria, spores, and viruses; incompatibility with anionic synthetic detergents; and rinsing requirement before use because of film formation on equipment surfaces. Some Gram-negative bacteria, such as *Pseudomonas spp.*, can grow in diluted QAC solutions.

d. Hydrogen Peroxides (H_2O_2)

H_2O_2 is a very effective germicide and kills vegetative cells, spores, and viruses. It is used for sanitation of equipment and containers used in the aseptic packaging of foods and beverages. Equipment and container surfaces can be sterilized in 15 min with a 30 to 50% solution; the treatment time can be reduced if the temperature of the solution is raised to 65.6 to 71.7°C (150 to 160ºF). Use of H_2O_2 in vapor phase can also be effective in killing microorganisms on food contact surfaces. Organic materials greatly reduce the germicidal effect of H_2O_2.

4.3.6 Microbiological Standards, Specifications, and Guideline

Microbiological standards, specifications, and guidelines are useful in keeping the microbial load of foods at acceptable levels by various methods, one of which is by controlling their access to foods. Microbiological standards of food are set and enforced by regulatory agencies to increase consumer safety and product stability. A standard dictates the maximum microbial level that can be accepted in a food. With proper sanitation and quality control, this level is generally attainable. Some examples are maximum acceptable levels of standard plate counts (SPCs) of Grade A raw milk, 100,000/ml; pasteurized Grade A milk, SPC 20,000/ml and coliforms <10/ml. However, very few foods have microbiological standards while many foods and food ingredients have microbiological specifications.

A specification indicates maximum permissible microbial load for the acceptance of a food or food ingredient. It should be attainable and agreed on by the buyers and sellers of the products. It is not set up or enforced by regulatory agencies. In the U.S., the military has microbiological specifications of foods purchased outside for army rations. For example, dried whole egg has the following specifications: aerobic plate count (APCs), 25,000/g; coliforms, 10/g; and Salmonella, negative in 25/g. The specifications discourage mixing of a microbiologically poor-quality product with a good quality product.

Microbiological guidelines are generally set either by regulatory agencies or food processors to help generate products of acceptable microbiological qualities. A guideline is set at a level that can be achieved if a food-processing facility uses good cleaning, sanitation, and handling procedures. It also helps detect if a failure has occurred during processing and handling, and thus alerts the processor to take corrective measures.

Self- Assessment Exercises 1

1. What do you understand by hazard analysis critical control point (HACCP)?
2. What are the physical agents used for sanitation of food

4.4 Summary

Spoilage and pathogenic microorganisms enter into food from different sources. One of the major objectives to produce a safe food with desirable shelf life is to minimize the access of microorganisms in food from various sources. This can be achieved by proper plant design, training personnel, designing equipment that can be sanitized effectively, and establishing an efficient cleaning and sanitation procedure. Many cleaning and sanitizing chemicals are available commercially. The aim will be to select agents that are suitable for a specific purpose. Adaptation of an efficient and approved procedure (by regulatory agencies) helps meet the required microbiological standards and specifications.

Sanitization in foods can be achieved by proper plant design, training personnel, designing equipment that can be sanitized effectively, and establishing an efficient cleaning and sanitation procedure. Many commercially available cleaning and sanitizing agents are Iodophores, Chlorine-based compounds; Quaternary Ammonium Compounds, and Hydrogen Peroxides. The aim will be to select agents that are suitable for a specific purpose.

4.5 Glossary

Culture: the whole complex of traditional behaviour which has been developed by the human race and is successively learned by each generation.

Sanitation: the maintenance of hygienic conditions, through services such as garbage collection and waste disposal.

Hazard: Unacceptable contamination, microbial growth, persistence of toxins or survival of microorganisms that are of a concern to food safety

Monitoring: Checking to determine if the criteria established by the critical control point(s) (CCP) have been achieved

Risk: Probability that a condition(s) will lead to a hazard

Severity: Seriousness of the consequences of the results of a hazard

4.5 References/Further Readings

Cords, B.R. and Dychdala, G.R. ((1993). Sanitizers: halogens, surface active agents and peroxides, in Antimicrobials in Foods, Davidson, P.M. and Branen, A.L., Eds., Marcel Dekker, New York, p. 469.

Marriot, N.G. (1989). Principles of Food Sanitation, Van Nostrand Reinhold, New York, pp. 71, 101.

Troller, J.A. (1982). Sanitation in Food Processing, Academic Press, New York, p. 21.

4.6 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercises 1

1. Hazard Analysis Critical Control Points (HACCP) is a system which provides the framework for monitoring the total food system, from harvesting to consumption, to reduce the risk of foodborne illness. The system is designed to identify and control potential problems before they occur.
2. Physical agents used for sanitation of food processing equipment include hot water, steam, hot air, and UV irradiation.