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HTM 419

FOOD ADDITIVES AND TOXICOLOGY

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Introduction

The course, FOOD ADITIVES AND TOXICOLOGY 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. 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 rudiments of food additives and toxicology.

Course Aim

The main aim of this course is to arm you with adequate information on the concept of food additives and toxicology in hospitality and tourism management. This will prepare the student for a future career in hospitality and related disciplines.

Learners' Outcomes

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.

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 food additives and toxicology principles for the study of Hospitality Management and Tourism.

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MODULE 1

UNIT 1 INTRODUCTION TO FOOD ADDITIVES

CONTENTS

1.1 Introduction

The Food Protection Committee of the Food and Nutrition Board (FNB) defined food additives as substances or mixture of substances, other than a basic foodstuff, which is present in a food as a result of any aspect of production, processing, storage or packaging. The term does not include dirt or contaminants.

Since prehistoric times, chemicals have been added to foods to perform special functions.

Although basic foods contain no additives, foods are processed for conversion into a variety of products. An increasing number of additives are now being generally used. Technological advancement in food production and processing has increased the variety and use of additives. Today, more than 2500 different additives are intentionally added to foods to produce desired effects. The use of additives is a well-accepted practice but is not without controversies.

In this unit, we shall explore some of the major benefits and risks of using additives. In subsequent units, each category of additives and some of the benefits and potential risks are explained in details.

1.2 Learning Outcomes

On completion of unit 1, you should be able to;

- discuss the meaning of food additives.
- discuss other aspects of food additives.
- analyse the categories of food additives.

1.3 Food additives

- **Preamble**

Food additives are utilized in the preparation and processing of almost all types of food in order to give favorable attributes to the food. It is a substance which is added to food to enhance its flavour, appearance or other favourable qualities. The Food Production Committee of the US National Research Council defined a food additive as "A substance or a mixture of substances other than a basic food stuff that is present in a food as a result of an aspect of production, processing, storage or packaging". According to US FDA (Food and Drug

Administration), a food additive is “any substance, the intended use of which results or may reasonably be expected to result directly or indirectly, in its becoming a component or otherwise affecting the characteristics of any food”. Although the term “food additives’ has been used frequently at present, its utilization has been in practice since ancient times; and probably dating back to much earlier than the hunter-gatherer era. Even though food additives confer much benefit to all sectors, such as the manufacturers, retailers and consumers, utilization of food additives must be carried out cautiously. Additives are either natural or synthetic chemicals. Present day consumers are turning to natural ingredients and bio based additives due to adverse effects caused by some chemicals. Therefore, plants derived substances are gaining a foot hold as preservatives, colorants, flavours, and even as antibacterial agents

1.3.1 E Numbers (International Numbering System) of Food Additives

Almost all safe-to-use food additives are given ‘E numbers’ by the European Food Safety Authority. In order to get to this status, the food additive must pass all the safety checks. Table 3.1 shows the general categorizes of food additives and their E numbers. However, when one food additive has more than one function, it is given only one E number. Chemical compounds and other species are constantly added to the list of safe-to-use food additives as the pass the safety checks.

An up to date list of food additives and their E numbers can be obtained from the official UK food standards agency web site;

Block of numbers	Food additives
E100-E199	Colors
E200-E299	Preservatives
E300-E399	Antioxidants and acidity regulators
E400-E499	Thickeners, stabilizers and emulsifiers
E500-E599	Anticaking agents

E600-E699	Flavor enhancers
E700-E799	Antibiotics
E900-E999	Glazing agents and sweeteners
E1000-E1599	Additional chemical

Table 3.1: E numbers of food additives

Self-Assessment Exercises 1

1. What is food additives with examples?
2. What is an E number in food additives?

1.4 Categories of Food Additives

Additives can be divided into six major classes. They include nutritional additives, preservatives, flavoring agents, coloring agents, texturing agents and miscellaneous additives.
In Europe and other parts of the world, the E system, developed by the European Union (EU), provides a list of several commonly used additives

Nutrients are not included in the E system. The Codex Alimentarius Commission Committee on Food Additives and Contaminants has developed an international numbering system (INS) for food additives based on the E system (Codex Alimentarius Commission, 2001). The INS system is broader than the E system and is intended as an identification system for food additives approved for use in one or more countries. It does not imply toxicological approval by Codex, and the list extends beyond the additives currently cleared by the Joint FAO/WHO Expert Committee on Food Additives (Codex Alimentarius Commission, 2001).

- **Nutritional additives:** Nutritional additives have increased in use in recent years as consumers have become more aware of nutritional benefits. They are not included as a functional class within the INS or E numbering system, although several of the additives are included under other functional classes and expectedly serve several functions in these products.

- **Vitamins,** which are also used, in some cases, as preservative are commonly added to cereals and cereal products to restore nutrients lost during processing or to enhance the overall nutritive value of the food. The addition of vitamin D to milk and B vitamins to bread has been associated with the prevention of major nutritional deficiencies.
- **Minerals** such as iron and iodine have also been of extreme value in preventing nutritional deficiencies. Like vitamins, the primary use of minerals is in cereal products.
- **Amino acids** and other proteinaceous materials are not commonly used in foods. However, lysine is sometimes added to cereals to enhance protein quality. Proteins or proteinaceous materials, such as soya protein, are also sometimes used as nutritional additives, although they are most commonly used as texturing agents.
- **Fiber additives** have gained increased popularity in recent years, with increase in consumer interest in dietary fiber. Various cellulose, pectin and starch derivatives have been used for this purpose. Recently, naturally derived fiber from apples and other fruits as well as sugar beets have been introduced as fiber additives. Fiber additives are not well defined and in reality have little or no direct nutritional value, although they do have indirect nutritional benefits. In some cases, fiber additives also provide improved texture to food products and are categorized in the INS and E system as bulking agents, thickeners, or stabilizers.

- **Preservatives:** There are basically three types of preservatives used in foods: antimicrobials, antioxidants, and anti-browning agents. These additives are grouped under the category of preservatives in the INS system.
    - **Antimicrobials**, with E and INS numbers ranging from 200 to 290, are used to check or prevent the growth of microorganisms. Antimicrobials play a major role in extending the shelf-life of numerous snacks and convenience foods and have come into even greater use in recent years as microbial food safety concerns have increased.
    - **Antioxidants** (INS 300–326 and E300–E326), are used to prevent lipid and/or vitamin oxidation in food products. They are also used primarily to prevent auto-oxidation and subsequent development of rancidity and off-flavor. They vary from natural substances, such as vitamins C and E, to synthetic chemicals such as butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT). Antioxidants are especially useful in preserving dry and frozen foods for an extended period of time.
    - **Anti-browning agents** are chemicals used to prevent both enzymatic and non-enzymatic browning in food products, especially dried fruits or vegetables. Vitamin C (E300), citric acid (E330), and sodium sulfite (E221) are the most commonly used additives in this category. These additives are classified as either antioxidants or preservatives in the INS system, but retain the same numbers as in the E system without the E.
- **Coloring agents:** Most coloring agents are used to improve the overall attractiveness of foods. A number of natural and synthetic additives are used to color foods. In addition, sodium nitrite is used not only as an antimicrobial, but also to fix the color of meat, by interaction with meat pigments. The colors are included in the E system as E100–E180 and in

the INS as 100–182. Although synthetic coloring agents continue to be used extensively, there has been significant increased interest in natural colorants.

- **Flavoring agents** comprise the greatest number of additives used in foods. There are three major types of flavoring additives: sweeteners, natural and synthetic flavors, and flavor enhancers. The most commonly used sweeteners are sucrose, glucose, fructose and lactose, with sucrose being the most popular. These substances, however, are commonly classified as foods rather than as additives. The most common additives used as sweeteners are low calorie or non-caloric sweeteners, such as saccharin and aspartame. They have had a major impact on the development of new foods.

The acidulants, which add a sour taste, often serve other purposes, including preservation. Flavor enhancers (INS 620–642 and E620–E640) magnify or modify the flavor of foods and do not contribute any flavor of their own.

- **Texturing agents:** Although flavoring agents comprise the greatest number of chemicals, texturing agents are used in the greatest total quantity. These agents are used to add to or modify the overall texture or mouth-feel of food products. Emulsifiers and stabilizers are the primary additives in this category.
- **Miscellaneous additives:** There are numerous other chemicals used in food products for specific but yet limited purposes. Included are various processing aids such as chelating agents; enzymes; anti-foaming agents; surface finishing agents; catalysts; and various solvents, lubricants and propellants.

Self-Assessment Exercises 2

1. What are the 6 categories of food additives?
2. Distinguish between the use of nutritional and

3.3 Aspects of Food Additives

- **Benefits of additives:** There are obviously many recognized benefits to be derived from additives. Some of the major benefits are a safer and more nutritious food supply, a greater choice of food products, and a lower-priced food supply.

*** Safer and more nutritious foods:** The preservative and nutritional additives used in foods increase the safety and overall value of many food products. The use of several antimicrobials is known to prevent food poisoning from various bacteria and molds. Antioxidants prevent the development of off-flavors. Also, they prevent the formation of potentially toxic autoxidation products and maintain the nutritional value of vitamins and lipids. The use of various nutritional additives such as vitamins is also of proven value in preventing nutritional deficiencies.

*** Greater choice of foods:** The availability of additives has allowed the production of numerous out-of-season foods and a variety of new food products. Additives have increased the development of convenience foods, snack foods, low-calorie and health promoting (functional) foods, exotic foods, and a variety of food substitutes.

*** Lower-priced foods:** On a national and global scale, additives make food more affordable to produce, and the production and distribution of food more efficient. Because they extend shelf-life, food manufacturers do not have to move product as soon as it is produced or in some cases refrigerate product, which lowers production, storage and transportation costs. Without food additives, the production and distribution of food would need to change to adjust to more limited shelf life. This would result in more cost to produce food, which would trickle down to the prices paid by buyers.

- **Risks of additives:** Despite the benefits attributed to food additives, for several years there have also been a number of concerns regarding the potential short- and long-term risks of consuming these substances. Critics of additives are concerned with both indirect and direct impacts of using additives.

*** Direct and indirect risks:** The indirect risks that have been described for additives are the converse of some of the benefits attributed to their use. While it is accepted that through additives, a greater choice and variety of foods have been made available, there is no question that additives have also resulted in the increased availability of food products with a low density of nutrients. These so-called junk foods, which include many snack items, can in fact be used as substitutes in the diet for more nutritious foods.

Of greater concern than the indirect risks are the potential direct toxicological effects of additives. Of particular concern are the hypersensitivity reactions of some consumers to some additives. Such cases can have a direct and severe impact on sensitive individuals, even when the chemicals are used at legally acceptable levels. Reactions to sulfites and other additives are examples of such a problem. With proper labeling, however, sensitive individuals should be able to avoid potential allergens.

*** Regulation:** Due to the difficulties in precisely defining the risks and benefits of individual additives, a legal, rather than a scientific, decision is commonly made regarding the safety of a food additive. In such a decision, the potential risks must be weighed against the potential benefits. The potential risks are well recognized, but their beneficial effects in food production, processing, and utilization are also felt to be essential to the maintenance of our current food systems. With the convenient, tasty, and nutritious foods demanded or desired by consumers and the increasing overall demand for foods as populations increase, food additives will continue to play an important and essential role in food production.

There will, however, continue to be concern regarding the potential risks associated with long-term consumption of small amounts of these chemicals and their possible interactive toxicological effects. As methods improve for evaluating these toxicological effects, some additives may be banned. At the same time, the same information may be used to develop safer new additives or techniques for using existing additives in a way that will lessen risk.

Self-Assessment Exercises 3

1. Give Reasons for and against the use of food additives
2. How are additives regulated?

1.6 Summary

In this unit, we have learnt:

* The definition and meaning of food additives and their E numbers (International Numbering System) for identification and classification

* Categories and types of food additives such as nutritional additives, preservatives, colouring agents, flavouring agents, texturing agents and miscellaneous additives

* Aspects of food additives including their benefits, risks and lower priced food

1.7 References/Further Reading

Angeline, J. F., Leonardos, G. P. 1973. Food additives—some economic considerations. Food Technol.April:40–50.

Anonymous, 1995. Food Additives: U.S. Products, Applications, Markets. Technomic Publishing,

Lancaster, PA. Branen, A. L. 1975. Toxicology and biochemistry of butylated hydroxyanisole and butylated hydroxytoluene. J. Am. Oil Chem. Soc. 52:59.

Codex Alimentarius Commission. 2001. Class names and the international numbering system for food additives.

Codex Alimentarius: Vol. 1A—General Requirements. www.fao.org/es/esn/ codex/standard/volume 1a/vol la 1a_e.htm.

Davidson, P. M., Branen, A. L. 1993. Antimicrobials in Foods. Marcel Dekker, New York.

Hanssen, M. 1984. E for Additives: The Complete ‘‘E’’ Number Guide. Thorsons Publishers, Wellingborough, England.

Hollingsworth, P. 1999. Keys to Euro-U.S. food product marketing. Food Technol. 53(1):24.

Institute of Food Technologists. 2000. IFT expert report on biotechnology and foods: benefits and concerns associated with recombinant DNA biotechnology-derived Foods. Food Technol. 54(10):61.

Jukes, D. 2001. Food Additives in the European Union. 2000. Food Law. www.fst.rdg.ac.uk/ foodlaw/additive.htm.

Sloan, A. E. 1997. Fats and oils slip and slide. Food Technol. 51(1):30.

Sloan, A. E. 1998. Food industry forecast: consumer trends to 2020 and beyond. Food Technol. 52(1):37.

Sloan, A. E. 1999. Top ten trends to watch and work on for the millennium. Food Technol. 53(8): 40.

Sloan, A. E. 2000. The top ten functional food trends. Food Technol. 54(4):33.

1.8 Possible Answers to Self-Assessment Exercises

Self-Assessment Exercises 1

1. Food addictives are substances that are added to food to maintain or improve the safety, freshness, taste, texture, or appearance of food are known as food additives. Some food additives have been in use for centuries for preservation – such as salt (in meats such as bacon or dried fish), sugar (in marmalade), or sulfur dioxide (in wine). (WHO; 2018)
2. E numbers ("E" stands for "Europe") are codes for substances used as food additives, including those found naturally in many foods such as vitamin C, for use within the European Union (EU) and European Free Trade Association (EFTA). Commonly found on food labels, their safety assessment and approval are the responsibility of the European Food Safety Authority (EFSA).

Self-Assessment Exercises 2

1) Additives can be divided into six major classes. They include nutritional additives, preservatives, flavoring agents, coloring agents, texturing agents and miscellaneous additives.
2) Nutritional additives are used for the purpose of restoring nutrients lost or degraded during production, fortifying or enriching certain foods in order to correct dietary deficiencies, or adding nutrients to food substitutes while Preservative food additives reduce the risk of foodborne infections, decrease microbial spoilage, and preserve fresh attributes and nutritional quality.

Self-Assessment Exercises 3

1. Reasons for and against the use of food additives

For:

- Food additives keep food safe by lengthening the shelf life.
- Many foods are kept safe to eat for longer through the use of preservatives (e.g., meat). These additives protect consumers from food-borne illnesses through limiting the growth of harmful bacteria. This allows foods to be kept on a shelf for longer and helps reduce waste.
- Food additives can make foods more appealing by enhancing the flavour, colour or texture.
- Manufacturers may add flavour enhancers, sweeteners, colours or thickeners to a food to make it more enjoyable for consumers by improving the final look and feel of the product.
- Food additives can enrich foods and improve or maintain nutritional value
- Some foods have additives added which improve the nutritional composition of the product. For example, by adding ascorbic acid (vitamin C) to a food.

Against:

- Food additives have been linked with adverse health effects such as cancer and allergic reactions.
- There are some additives that have controversial research linking them with carcinogenic (cancer-causing) properties. For example, sodium nitrite, used to preserve meat has been linked to increased levels of bowel cancer.
- Food additives have been linked with affecting some children's behaviour and health.
- Some food colourings and preservatives have been linked to hyperactivity in children when consumed in extremely high quantities.

- Some food additives have been related to headaches and migraines in children, as they are more sensitive to certain substances than adults.
- Food additives can make food products appear 'better' than they are.
- Additives such as bulking agents or flavour enhancers may be added to lower quality food products to make them appear more attractive to consumers.

2. The Food Additives require FDA premarket approval based on safety data submitted to FDA in a food additive petition. FDA issues food additive regulations specifying conditions of use (i.e. technical functions, categories of food, and maximum levels of use) under which a food additive has been demonstrated to be safe.

UNIT 2 FOOD ADDITIVE INTAKE ASSESSMENT AND REGULATORY BODIES

CONTENTS

2.1 Introduction

Food additives are special chemicals that are added to our foods purposefully, and are meant to be in the food at the time of consumption. Both international organizations and national governments generally evaluate the safety of food additives. The goal of assessment is to take into account local food supply and cultural differences in dietary habits that may influence the intake of food additives.

Food additive intake assessment has three major goals. They include:

* Monitoring the intake of chemicals and relating it to the acceptable daily intake (ADI) values

* Identifying consumer groups that are at risk for food additive intake close to or higher than ADI values

* Providing information for regulatory bodies for reassessing the food additive regulations, in case of high intake in all or some consumer groups.

The major aim of intake assessment is to protect the health of consumers. Another purpose of it is to assist in developing food additive regulations.

2.2 Learning Outcomes

On completion of this unit, you should be able to:

- discuss the scope and purpose of food additive intake assessment
- discuss Nigerian regulatory bodies and their roles
- discuss National Codex Committee (NCC); its contact point and technical committees
- analyse the regulation of maximum levels of food additives
- evaluate NAFDAC’s regulatory and awareness strategies
- evaluate the challenges of regulatory control of food and toxicants in Nigeria

2.3 Food Additive Intake Assessment

- **Preamble**

The safety evaluation of food additives is based on the assessment of toxicity of the chemicals added to food. The rationale of intake assessment is to determine the likelihood and extent to which ADI values may be exceeded. The Acceptable Daily Intake (ADI) value is determined by the Joint FAO/WHO Expert Committee on Food Additives (JECFA). The ADI value defines an estimate of the amount of food additives, expressed on a body weight basis that can be ingested over a lifetime without appreciable health risk (WHO, 1987).

*** Scope and purpose of food additive intake assessment:** The assessment sets the limits on food additive intake and also provides the goals for the assessment procedures. Several approaches can be taken, and food additives can be grouped based on the safety data of their toxicological classification (as shown in Table 1 below). However, it is important to assess the use of specific components, whether additive or ingredient, and to define the safety data needed for each purpose. This then forms the basis for intake assessment and risk evaluation procedures.

Table 1	**Toxicological Classification of Food Additives Based on Available Safety Data**
Group A	Substances with an established ADI value
Group B	Substances generally regarded as safe
Group C	C Substances with inadequate data
Group D	Flavoring components
Group E	E Natural components used as additives without any scientific safety data or with very limited data

Table 1: Toxicological Classification of Food Additives Based on Available Safety Data

*** Regulation of maximum levels of food additives:** In the United States, the principle of certain food components being generally recognized as safe (GRAS) was established in early legislation and later rigorously defined to include scientific evidence. Other regulations are included in the Code of Federal Regulations on specific food additives.

In the European Union, three major directives regulate the use of food additives in member countries. In Australia and New Zealand, the regulation is similar to that in Europe. In Japan, differences exist in the regulation of all additives from natural sources, while strict regulation concerns chemical additives. Usually the regulation is based on the acceptable daily intake (ADI) values determined by the JECFA. This committee started establishing the ADI values as early as 1956. The ADI value is not an exact figure or a mathematical value, but it gives an estimate of how much of a chemical can be relatively safely ingested daily by normal consumers.

Self-Assessment Exercises 1

1. Give the Toxicological Classification of Food Additives Based on Available Safety Data
2. What are the legal requirements that additives must meet?

2.4 Nigerian Regulatory Situation: Bodies with Roles to Play

In Nigeria the main national legislations relating to food safety include the following:

1. The Public Health Laws, 1917 now known as Public Health Ordinance Cap 164 of 1958
2. The Food and Drugs Decree, No. 35 of 1974
3. The Standards Organizations of Nigeria (SON) Decree, No. 56 of 1971
4. The Animal Disease Control Decree, No. 10 of 1988
5. The Marketing of Breast Milk Substitute Decree, No. 41 of 1990
6. The National Agency for Food and Drugs Administration and Control (NAFDAC) Decree No. 15 of 1993 Laws of the Federation.

Many health problems encountered in Nigeria arising from consumption of unsafe food are not new. Contamination of food and feeds arising from naturally occurring toxicants, microbiological contaminants, chemical contaminants such as additives used above the permitted levels, pesticide and veterinary residues in food or as toxic components from food processing could have deleterious effects in humans and animals. Naturally occurring toxicants are of both plant and animal origin.

Bacterial contamination, fungal toxins, pesticides and toxic metals are the food contaminants of major health concerns. Bacterial food-borne diseases caused by species of Salmonella, Clostridium, Campylobacter and Escherichia are of no lesser health concerns contributing to the morbidity and mortality rates of the country. The presence of mycotoxins produced by toxigenic fungi in food and feed exacerbates endemic diseases such as malaria and hepatitis with consequent acute and chronic effects.

In Nigeria, in the bid to tackle these problems, several bodies and agencies are designated to regulate and monitor food safety standards. They are listed below.

- **Bodies or Agencies Responsible for Regulating and Monitoring Food Safety Standards and Practices in Nigeria are:**

1. Federal Ministry of Health
2. Federal Ministry of Agricultural and Rural Development
3. National Agency for Food and Drug Administration and Control (NAFDAC)
4. Standards Organization of Nigeria (SON)
5. The States and Local Governments

The specific roles of these agencies include:

- **Federal Ministry of Health**

The Federal Ministry of Health has the responsibility for formulating national policies, guidelines and regulations on food hygiene and safety as well as the monitoring of their implementation. It is also responsible for establishing guidelines for the requirements for the nutritive value of food, and monitoring of food environments and handlers, control of food borne diseases, the quality of public water supply as well as national and international matters relating to food.

- **Federal Ministry of Agriculture and Rural Development**

The Federal Ministry of Agriculture and Rural Development has the responsibility for promoting good agricultural practices and new agricultural technologies in conformity with food safety polices and regulation standards.

- **National Agency for Food and Drug Administration and Control (NAFDAC)**

NAFDAC is the parastatal under the Federal Ministry of Health saddled with the responsibility for regulation and control of imported and locally produced foods, drugs and bottled water in Nigeria.

- **Standards Organization of Nigeria (SON)**

SON is charged with responsibility for the formulation of standards on the composition of imported and locally manufactured food and other products in Nigeria. There are 100 standards on food and food products as well as good number of codes of hygienic practices for food and food products which have been established by the Standards Organization of Nigeria. These standards and codes are reviewed periodically to meet current trends in technological and industrial developments.

- **States and Local Governments**

The States and Local Governments Authorities, collaborate with National Primary Healthcare Development Agency — an agency under the Federal Ministry of Health — monitor and regulate street food vending and outlets, catering establishments and traditional markets food services.

2.4.1 National Codex Committee (NCC)

Nigeria is a member of the Codex Alimentarius Commission, a Joint FAO/WHO Food Standards Programme. The National Codex Committee (NCC) was established in July 1973 by the approval of the Federal Executive Council, and reconstituted in 2002, to incorporate all stakeholders to enable the committee function effectively towards providing relevant inputs and asserting the country's position at the Codex Alimentarius Commission in view of the implications for food safety and quality, protection of consumer health, fair practices in food trade as well as the enhancement of the national economy. The National Codex Committee (NCC) operates within the provisions of the NCC Procedural Manual that sets out its General Rules and the other internal procedures necessary to achieve the objectives of the National Codex Committee; lists out the core functions of the National Codex Committee Secretariat, their four Technical Committees and their terms of reference. Also, it sets out the guidelines for meetings of the NCC and its technical committees and lists their membership. The chair of the NCC is currently the Federal Ministry of Health but with the review of the NCC Procedural Manual, will become rotational between the Federal Ministry of Health and the Federal Ministry of Agriculture and Rural Development. The Secretariat of the NCC and Codex Contact Point (CCP) is the Standards Organisation of Nigeria (SON).

- **Codex Contact Point (CCP)**

This is primarily a coordinator and focal point for Codex activities within the country, and is the link between the country and the Codex Alimentarius Commission (and its Secretariat). It receives all the correspondence from the Codex Secretariat and Codex Committees and also invitation letters to attend Codex Committee and Commission meetings and coordinates all the necessary activities to facilitate the desired response. CCP, which also serves as the secretariat for the National Codex Committee in Nigeria, is domiciled in the Standards Organization of Nigeria.

- **National Codex Committee Technical Committees**

There are have four technical committees that deliberate on Codex texts and Circular Letters received from the Codex Secretariat requiring government comments at steps 3 and 6 of the 8-step standard setting procedure of the Codex Alimentarius Commission. The technical committees meet to synthesize the national position and prepare the country's delegation that would attend Codex Committee and Commission meetings. The recommended country's positions are endorsed by the National Codex Committee and forwarded by the Codex Contact Point to the Codex Secretariat, the respective Codex Committee and the Codex Commission as the case may be.

2.4.2 National Agency for Food & Drugs Administration & Control (NAFDAC)

NAFDAC is the regulatory authority in Nigeria with the mandate to regulate and control the manufacture, importation, exportation, advertisement, distribution, sale and use of food, drug, cosmetics, medical devices, chemicals, detergents and packaged water. These items are often referred to as regulated products. NAFDAC is the lead Agency for ensuring food safety and quality in Nigeria.

❖ **Regulatory Strategies**

* **Product Registration**: The Agency uses product registration to establish and monitor the ownership and/or distributorship of the products it regulates, which are generally known as regulated products: their safety; quality; labeling; claims etc. NAFDAC employs a structured and

systematic procedure for product registration, at the end of which the product is assigned a NAFDAC Registration Number, which is an attestation to the safety, quality and appropriateness for its intended use. The registration process involves:

- ✓ Documentation
- ✓ Labeling
- ✓ Inspection
- ✓ Product Approval Committee Meetings

* **Consultative Meetings:** NAFDAC encourages sectoral groups, small and medium scale entrepreneurs etc to form umbrella associations (e.g. Association of Food, Beverage and Tobacco Employers (AFBTE); All Farmers Association etc). These organizations are encouraged to self regulate their practices and can easily arrange for consultative meetings with the Agency, where their views and concerns are addressed and taken into account when making regulatory decisions that concern them.

* **Public Enlightenment Campaigns**: The Agency organizes public enlightenment campaigns on topical and emerging issues using the electronic media, print media and physical presence at campaigns held at grassroots levels, where the rural dwellers are invited with the cooperation and involvement of their local chiefs to inform and educate the populace.

* **Training and Publications:** NAFDAC organizes international, national and in-house capacity building training programmes consistently for staff, the industry and the general public. There are also collaborations and exchange programmes with credible regulatory authorities and international bodies such as the United States Food and Drug Administration (USFDA), US Department of Agriculture (USDA), International Atomic Energy Agency (IAEA), World Health Organization (WHO) etc.

2.4.3 Challenges of Regulatory Control of Food Borne Toxicants in Nigeria

The challenges of regulatory control of food borne toxicants range from variations in the quality of raw materials supplied to the food producers. In many cases, food processing procedures are sourced separately and pooled together, having many food handlers and middlemen with the risk of practices that expose the food to contamination. Also, inadequate infrastructure and laboratory capacity and expertise, insufficient number of regulatory officers, inadequate coordination of food safety activities along the value chain to insufficient knowledge by food handlers pose a lot of challenge.

Certain unwholesome practices such as improper use of agrochemicals by traders of food commodities. Poor handling and storage of products such as melon seeds, groundnuts, rice etc lead to fungal growth and mycotoxin production, at levels that exceed the acceptable limits.

Street vended foods are an important component of the food supply chain but unfortunately are generally prepared in unhygienic conditions with poor food handling, unhygienic surroundings and limited water supply. These conditions expose the food to microbiological contamination and could be a source of illness for the consumer.

All these challenges could be addressed through public enlightenment, better coordination of roles along the food value and food supply chain, capacity building, improved infrastructure, training from the farm to the processing or preparation levels, adequately equipping the producers and regulators to perform their functions better through training and retraining in addition to providing the necessary working tools.

Minimum quality requirements are included in the food laws to ensure the foods produced are unadulterated and are not subjected to any fraudulent practices intended to deceive the consumers. Also, food laws should cover the total chain beginning with provisions for on-farm controls and early processing through to final distribution and use by consumers.

Self-Assessment Exercises 2

1. List Bodies or Agencies Responsible for Regulating and Monitoring Food Safety Standards and Practices in Nigeria
2. State the registration process for products by NAFDAC

2.5 Summary

The estimation of food additive intakes can be used, not only to ensure that the food supply is safe, but also to review the changing use of additives in food in order to maintain relevant regulations for both consumer safety and food processors. Although ADI values are only as good as the toxicological studies in animals and the methods used for their calculation, they are useful for food safety evaluation.

Generally, safety regulations apply to legislation regulating the production, processing, packaging, labeling, distribution and sell of food. Therefore, it covers the regulation of food control as well as food safety.

In this unit, we have learnt the; Scope and purpose of food additive intake assessment, Regulation of maximum levels of food additives, Nigerian regulatory bodies and their roles, National Codex Committee (NCC); its contact point and technical committees, NAFDAC's regulatory and awareness strategies, Challenges of regulatory control of food and toxicants in Nigeria

2.6 References/Further Readings

Buchet, J. P., Lauwerys, R. 1983. Oral daily intake of cadmium, lead, manganese, copper, chromium, mercury, calcium, zinc and arsenic in Belgium: a duplicate meal study. Food Chem. Toxicol. 21:19–24.

Fondu, M. 1992. Food additives: dietary surveys and calculation of consumption. Medecine et Nutrition 20:163–175.

Gunderson E. L. 1995. FDA total diet study, July 1986–April 1991, dietary intakes of pesticides, selected elements, and other chemicals. J. AOAC Intern. 78:1353–1363.

WHO 1987. Principles for the safety assessment of food additives and contaminants in food. Environmental Health Criteria 70. World Health Organization, Geneva.

Wodicka, V. O. 1980. Legal considerations on food additives. In: CRC Handbook on Food Additives, Vol. II, 2nd ed., Furia, T. E. (Ed.). CRC Press, Boca Raton, Florida, pp. 1–12.

2.7 Possible Answers to Self-Assessment Exercises

Self-Assessment Exercises 1

1.

	Toxicological Classification of Food Additives Based on Available Safety Data
Group A	Substances with an established ADI value
Group B	Substances generally regarded as safe
Group C	C Substances with inadequate data
Group D	Flavoring components
Group E	E Natural components used as additives without any scientific safety data or with very limited data

2. A food additive petition must contain information identifying the substance, its proposed use (as reflected in its labeling), all relevant data concerning its effect on food and residue detection methodologies, and full reports of safety studies.

Self-Assessment Exercises 2

List Bodies or Agencies Responsible for Regulating and Monitoring Food Safety Standards and Practices in Nigeria

1. In Nigeria the main national legislations relating to food safety include the following:
    i. Federal Ministry of Health
    ii. Federal Ministry of Agricultural and Rural Development
    iii. National Agency for Food and Drug Administration and Control (NAFDAC)
    iv. Standards Organization of Nigeria (SON)
    v. The States and Local Governments
2. The registration process involves:
    - Documentation
    - Labeling
    - Inspection
    - Product Approval Committee Meetings

UNIT 3 RISKS AND BENEFITS OF FOOD ADDITIVES

CONTENTS

3.1 Introduction

A treatise on food additives would be incomplete without a discussion of the risks and benefits associated with their use. Any risks associated with the use of food additives should be placed, in perspective, with other food-associated risks and with the risks associated with the use of alternative additives or specific additive-free formulations. This unit will focus on the risks and benefits associated with food additives as well as generally recognized as safe (GRAS) and prior sanctioned food ingredients.

3.2 Learning Outcomes

On completion of this unit, you should be able to:

- discuss the functions and usage of food additives

- discuss regulation of food additive usage
- discuss regulatory assessment of the risks of food additives
- evaluate the risks and benefits of food additives in food

3.1 Functions and Usage of Food Additives

Hundreds of chemical additives are incorporated into foods directly or migrate into foods from the environment or packaging materials. A food additive can sometimes be defined as a substance whose intended use will lead to its incorporation into the food or will affect the characteristics of the food. These additives generally provide some type of benefit to the food producer, processor, or consumer. For the consumer, additives can improve organoleptic qualities of foods, improve the nutritive value, or ease the preparation of ingredients and meals. Typical additive benefits to the food producer or processor include improving product quality, safety, and variety.

- **Functions of food additives:**

Additives may be found in varying quantities in foods, perform different functions, provide ingredients and function synergistically with other additives. Their functions can usually be classified as one of the following:

* maintain or improve nutritional quality,

* maintain or improve product safety or quality,

* aid in processing or preparation, and

* enhance sensory characteristics (FDA, 1979, 1992).

Additives that affect nutritional quality are primarily vitamins and minerals. In some foods, these may be added to enrich the food or replace nutrients that may have been lost during processing. In other foods, vitamins and minerals may be added for fortification in order to supplement nutrients that may often be lacking in human diets. Preservatives or antimicrobial substances are used to prevent bacterial and fungal growth in foods. These additives can delay spoilage or extend the shelf life of the finished product. Antioxidants are additives that also can extend the shelf life of foods by delaying rancidity or lipid oxidation. Additives that maintain product quality may also ensure food product safety for the consumer.

Additives that are used as processing or preparation aids usually affect the texture of ingredients and finished foods. Some of these are classified as emulsifiers, stabilizers, thickeners, leavening agents, humectants, and anti-caking agents. Chemicals in this group of food additives are also used to adjust the homogeneity, stability and volume of foods. The fourth major function of food additives is to enhance the flavor or color of foods to make them more appealing to the consumer. Flavoring chemicals may be used to magnify the original taste or aroma of food ingredients or to restore flavors lost during processing. Natural and artificial coloring substances are added to increase the visual appeal of foods, to distinguish flavors of foods, to increase the intensity of naturally occurring color, or to restore color lost during processing.

- **Usage of food additives:**

Chemicals that are added to foods may be manmade or derived from natural plant or animal sources. Also, additives may be synthesized for foods that are chemically or functionally identical to those that may be derived from natural sources.

In the case of color additives, synthetic colors are also identified as certifiable colors. Each batch of these coloring chemicals is tested by the manufacturer and the regulatory body concerned to ensure the safety, quality, consistency, and strength of the color additive prior to its use in foods. Color additives that are exempt from the certification process include pigments derived from natural sources such as vegetables, minerals or animals, or the manmade equivalents of naturally derived colors. Examples include annatto extract, paprika, turmeric, and beet powder.

If an additive from a natural source is added to a food, then its package label should indicate that. Additives are further classified by how they are added to foods. Some additives are directly added to foods and ingredients, while others may be added indirectly through contact with packaging materials, for example, the preservatives BHA and BHT on the inside of breakfast cereal bags.

Some undesirable food additives may be unintentionally added to foods. For example, pesticides and fumigants may come in contact with produce and grains during growing, harvesting, and storage. While these chemicals may have permitted uses for some crops, they may be illegal for use on others. Sometimes pesticides are mistakenly or unintentionally applied at the wrong concentration or too soon before harvest. Pesticides have been found, infrequently, on certain crops and at certain concentrations that are not permitted by the Environmental Protection Agency. Other examples of unintentional addition of food chemicals are those that migrate into foods from packaging materials, especially plastics, and those that occur from poor storage practices. Numerous chemicals may find their way into foods through contamination from the environment. Frequently cited examples include dioxin, polychlorinated biphenyl compounds (PCBs), and heavy metals such as lead and mercury.

Food additives are generally intended to provide important benefits to the producer or consumer of foods. But sometimes these additives cause unwanted or unhealthful effects. Often these undesirable effects of food additives are due to their excessive or accidental use; usage at an inappropriate stage of production, processing, or storage; or from a lack of purity or quality.

Extensive research has been conducted on many additives to show they are safe for consumption and are effective for their prescribed function. For other additives, widespread and long-term use by food processors has demonstrated safety and efficacy.

3.3.1 Regulation of Food Additive Usage

1) Federal Authority: Numerous research studies have confirmed that appropriate use of many additives is safe for human health and provides a benefit to the processor, preparer or consumer. Other additives are considered safe and efficacious due to successful widespread use over many years. Multiple federal agencies, laws and regulations work together to ensure the safety and efficacy of thousands of food additives, but there are great differences in how many of these additives are regulated. The Food, Drug and Cosmetic Act of 1938 gives the U.S. Food and Drug Administration authority to regulate foods, ingredients, and their labeling. The 1958 Food Additives Amendment to the FD&C Act requires FDA approval for the use of a new additives prior to its inclusion in food. Also this Amendment requires the additive manufacturer to prove an additive's safety for its recommended use.

Food additives are defined as substances which may, by their intended uses, become components of food, either directly or indirectly, or which may otherwise affect the characteristics of the food. The term specifically includes any substance intended for use in producing, manufacturing, packing, processing, preparing, treating, packaging, transporting, or holding the food, and any source of radiation intended for any such use (FDA, 1998a). This definition does not include some classes of additives such as pesticide chemicals for raw agricultural products, new animal drugs, certified colors, or colors exempt from certification. These additives are similarly regulated, but under other laws or acts. Additionally, food additives that have a history of safe usage are exempted from the regulation process described in the Food

Additives Amendment. One group of these additives is known as ‘‘GENERALLY RECOGNIZED AS SAFE’’ (GRAS), (e.g., salt, vitamins, etc). They have been generally recognized, by experts, as safe based on their extensive history of use in foods before 1958, or based on published scientific evidence. Another group of exempted additives is designated as prior sanctioned additives. These are substances that the FDA or U.S. Department of Agriculture (USDA) had determined were safe for use in specific foods prior to 1958 (e.g., sodium nitrite to preserve meat). Other important federal regulation of food and color additives is described in the 1960 Color Additive Amendment to the FD&C Act, the 1990 Nutrition Labeling and Education Act, and the 1996 Food Quality Protection Act. Current good manufacturing practice (CGMP) regulations can limit the quantity of food and color additives used in production. Manufacturers may only use the amount of an additive necessary to achieve a desired effect.

2) Monitoring: In the case of pesticides for foods and animal feeds, the U.S. Environmental Protection Agency and the FDA have regulatory responsibilities for the approval and monitoring of pesticide use. Three major legislative acts describe the authority of the EPA and FDA to regulate pesticide chemicals (EPA, 1998). The Federal Insecticide, Fungicide and Rodenticide Act prescribes that the EPA is responsible for registering or licensing pesticide products for use in the United States. The Federal Food, Drug and Cosmetic Act governs the maximum level of pesticide residues allowed in or on specific human foods and animal feeds. In 1996, the Food Quality Protection Act (FQPA) amended these two acts in several respects. For example, to assess the risks of pesticide residues in foods or feeds, the FQPA requires that the combined exposure from dietary and other non-occupational sources be considered. Also, when setting new or adjusted tolerances for pesticides, the EPA must consider any special risks to infants and children.

3) NAFDAC's Food Additives Regulations 2019 repealed the Food Additives Regulations 2005. According to NAFDAC, "the repeal of these Regulations specified in Regulation 17(1) shall not affect anything done or purported to be done under the repealed Regulations". Some details of the 2019 regulations are as follows:

* **Scope** These Regulations shall apply to ¬ The labelling of food additives sold as such whether by retail or other than by retail, including sales to caterers and food manufacturer, and ¬ Food processing aids; any reference to food additives shall include food processing aids.

* **Prohibition:** No person shall manufacture, import, export, distribute, advertise, display for sale or use any food additives, except food additives set out in the prescribed standards ¬ Food additive shall be incorporated in the food in a quantity within the limits prescribed for such food and food additive in the National Standards for the particular food and Codex standards where applicable and as prescribed by the Agency ¬ Where the limit prescribed for a food additive in the Codex standard is stated to be "Good Manufacturing Practice", the amount of the food additive added to a food in the manufacturing and processing shall not exceed the amount required to accomplish the purpose for which that additive is required in that food.

*** Food Additives:** Food additives not to be described or presented on any label or in any labeling: ¬ In a manner which is false, misleading or is likely to create an erroneous impression regarding its character in any respect ¬ By words, pictorials or other devices, which refer to or are suggestive— directly or indirectly— of any other product with which such food additives might be confused, or in such a manner as to lead the purchaser or consumer to suppose that the food additive is connected with or derived from such other product ¬ Food additives with a shelf life not exceeding 18 months shall carry the date of minimum durability using words such as 'will keep at least until…...'. The words 'for food use' or a statement substantially similar thereto shall appear in a prominent position on the label.

4) Labelling: The risks or benefits of food additives and ingredients must be clearly displayed on labels for consumers. The FD&C Act requires, in virtually all cases, a complete listing of all the ingredients of a food. The Nutrition Labeling and Education Act, which amended the FD&C Act, requires most foods to bear nutrition labeling and requires food labels that bear nutrient content claims and certain health messages to comply with specific requirements.

5) NAFDAC's Regulation on Labeling of Synthetic Color and Mixture of Colors in Food

The aspect of this regulation clearly states that: No person shall manufacture, import, export, distribute, advertise, display for sale or sell synthetic color, or a mixture of colors, for use in food, unless the label carries the

- Lot number of the mixture
- Words "food grade colour", and
- Common name of the individual colors (synthetic or inorganic) in the mixture.

Self-Assessment Exercises 1

1. Enumerate the classes of additives according to function
2. Describe the prohibition by NAFDAC's Food Additives

3.4 Regulatory Assessment of the Risks of Food Additives

1) Determination of safe and effective quantities for foods: For some additives, especially vitamins and minerals, the quantity added to a finished food product may not be sufficient to achieve an intended health benefit. Some foods that are commonly consumed by the majority of the population may be supplemented with various vitamins or minerals. A single serving of a fortified food may not provide the same health benefit as regular consumption of a fortified food. For example, iodine is added to table salt to provide a regular source of this important mineral. Table salt is regularly consumed, and iodine is often lacking in typical diets. The determination of a beneficial, yet safe, quantity of iodine to add to table salt must consider the typical consumption of salt over the lifetime of the consumer.

While a food additive may provide a benefit to a processor or a consumer when used as intended, the use of an inappropriate quantity may be deleterious to the food or to the consumer. If an additive is used in excess to process a product, then the desired effect may not be achieved, or else there may be an undesirable quality defect attributed to the product. For example, if an artificial sweetener such as aspartame is added to a beverage in a high concentration, then the product may be too sweet and rejected by consumers. Safety determinations of additive use should consider the effects of accidental or intentional consumption of a high quantity of an additive that is beyond its prescribed use level.

Toxicological principles for assessing the safety of food additives have been developed (FDA, 1993). Also an additive may be injurious to health, when consumed in moderate doses over extended time periods. When the risks or benefits of food additive use are considered, estimation must be made of the long-term or lifetime consumption of the additive. These substances may have cumulative effects on health, may interact with other biological or chemical compounds in the body, or may elicit different responses in consumers of different ages or health status.

2) Risk assessment: The determination of the appropriate uses and concentrations of additives to allow in foods can be a complex process. Directly, or indirectly, added additives may have a demonstrated usefulness to a food processor or consumer, but they may also have harmful toxicological effects, when consumed in excess quantities or by sensitive population groups.

In order to determine if a food additive can become a health hazard to the consumer, the inherent toxicity of the additive and the typical consumer consumption or exposure must be estimated. Both the short-term and the lifetime cumulative exposures should be considered, since some additive usage may result in acute or chronic effects that are detrimental to health. To protect individuals from the possible adverse effects of these substances, studies to assess the risk of exposure to chemical residues should be performed. The basic components of a risk assessment include hazard identification, dose-response assessment, exposure assessment and risk characterization (NRC, 1980, 1983).

*** Hazard identification** is the process where specific chemicals are causally linked to the exhibition of particular health effects. These may include illnesses, birth and developmental defects, and reproductive abnormalities. Also it must be determined, if consumption of a chemical could lead to the development of cancer. Cancer usually develops after long-term exposure to a carcinogenic substance. Other adverse health effects may be observed after a short-term or high-level exposure to an additive. In other words, the use of some additives may only be hazardous when consumed in specific quantities.

*** Dose Response Assessment** is used to predict the relationship between human exposure to the chemical and the probability of adverse effects. For carcinogens, it is assumed that no threshold level of exposure may exist, which implies that carcinogens may be hazardous when consumed in any quantity. For non-carcinogenic hazards, toxic effects will not generally be observed until a minimum or threshold dose is reached.

*** Exposure Assessment** is necessary to predict the likely amount of human exposure to an additive. For many foods and food additives, it can be difficult to determine how much may be consumed by a particular population and how consumption varies among individuals. Some population subgroups may be exposed to greatly different quantities of food additives. Food consumption patterns vary greatly due to consumer age, gender, ethnicity, socioeconomic status, health status, and so on.

*** Risk Characterization** describes the origin, magnitude, and uncertainties of estimates of the health risk. Considerations for evaluating the overall risk of using a food additive must include whether it has specific hazardous properties, a prediction of the likelihood of adverse effects based on exposure, and an estimation of the amount of exposure.

3.4.1 Risks and Benefits of Food Additives in Food

Risks: The GRAS ingredients would be included in this classification. Although GRAS ingredients are not legally food additives, the public perceives no distinction. This class includes thousands of substances. Any potential hazard to humans from a certain food additive depends on the toxicity of the food additive and the level at which the additive is ingested. Human exposure to indirect additives is difficult to measure, but this exposure is minimal. The majority of direct food ingredients are used on the basis of a determination that they are GRAS or prior sanctioned. Review of some items on the GRAS list has indicated that the majority present no significant hazard with normal use. The other direct food additives used in foods have been approved, and their uses are regulated by the FDA.

Benefits: The benefits derived from the food supply generally fall into four categories:

***** Health benefits that reduce some health risk or provide some health benefits such as improved nutrition,

* Supply benefits relating to abundance, diversity, and economic availability,

* Hedonic benefits that provide sensory satisfaction, and

* Benefits that lead to increased convenience (Darby, 1980; Food Safety Council, 1980).

Food additives can play an important role in each of these categories of benefits by improving health, increasing supply, enhancing appeal, or improving convenience. Of these benefits, health benefits should be given the greatest consideration, while supply benefits are second in importance. Increased convenience and improved appeal are the least important.

Self-Assessment Exercises 2

1. How is the safety of food additives evaluated?
2. What are some of the risks of food additives?
3. What is the risk characteristics of a food additive?

2.5 Summary

There are a lot of benefits in the functions and usage of food additives. All the benefits can be classified as either health benefits or hedonic benefits. Health benefits are of two types: those that prevent or reduce the incidence of specific diseases and those that provide enhanced nutrition. Hedonic benefits include improved color, flavor and texture to enhance consumer appeal.

Despite the several benefits associated with the functions and usage of food additives, they are accompanied by numerous health risks. Hence many regulatory bodies have evolved to monitor and control their usage. One of the most important regulatory agencies in Nigeria is National Agency for Food and Drug Administration and Control (NAFDAC).

In this unit we have learnt; Functions and usage of food additives, Regulations of food additive usage by Federal Authorities, monitoring, NAFDAC's Food Additives Regulations 2019 and labeling, Regulatory assessment of the risks of food additives through determination of safe and effective quantities for foods, new additive approval and risk assessment, Risks and benefits of food additives in food

2.6 References/Further Reading

Darby, W. J. 1980. The nature of benefits. Nutr. Rev. 38:37–44.

EPA. 1998. Laws affecting EPA's pesticide programs. http:/ /www.epa.gov/pesticides/citizens/ legisfac.htm.

FDA. 1979. More Than You Ever Thought You Would Know About Food Additives. FDA Consumer HHS Publication No. (FDA) 79–2115.

FDA. 1992. Food additives. FDA/IFIC Brochure, Jan. 1992.

FDA. 1993. Food color facts. FDA/IFIC Brochure, Jan. 1993.

FDA. 1998a. Food Additives Permitted for Direct Addition to Food for Human Consumption. Code of Federal Regulations. Title 21, Part 172, Government Printing Office, Washington, D.C.

FDA. 1998b. Food additives and premarket approval. http:/ /vm.cfsan.fda.gov/_lrd/foodadd.html.

FDA. 1998c. Olestra. Code of Federal Regulations. Title 21, Part 172.867, Government Printing Office, Washington, D.C.

Food Safety Council, Social and Economic Committee. 1980. Principles and processes for making food safety decisions. Food Technol. 34(3):89–125.

NRC (National Research Council). 1980. Risk assessment/Safety Evaluation of Food Chemicals.

Report of the Subcommittee on Food Toxicology. Committee on Food Protection, Food and Nutrition Board. National Academy Press, Washington, D.C.

NRC (National Research Council). 1983. Risk Assessment in the Federal Government: Managing the Process. Report of the Committee on the Institutional Means for Assessment of Risks to Public Health. Commission on Life Sciences. National Academy Press, Washington, D.C.

WHO. 1987. Principles for the safety assessment of food additives and contaminants in food. Environmental Health Criteria #70. World Health Organization, Geneva.

3.7 Possible Answers to Self-Assessment Exercises

Self-Assessment Exercises 1

1. Their functions can usually be classified as one of the following:
   a) maintain or improve nutritional quality,
   b) maintain or improve product safety or quality,
   c) aid in processing or preparation, and
   d) enhance sensory characteristics (FDA, 1979, 1992).
2. Prohibition: No person shall manufacture, import, export, distribute, advertise, display for sale or use any food additives, except food additives set out in the prescribed standards (Food additive shall be incorporated in the food in a quantity within the limits prescribed for such food and food additive in the National Standards for the particular food and Codex standards where applicable and as prescribed by the Agency (Where the limit prescribed for a food additive in the Codex standard is stated to be “Good Manufacturing Practice”, the amount of the food additive added to a food in the manufacturing and processing shall not exceed the amount required to accomplish the purpose for which that additive is required in that food.

Self-Assessment Exercises 2

1. The safety of food additives is assessed by evaluating toxicity data. Hazard characterization involves both “dose-response extrapolation” and “dose scaling”.
2. Some food additives can cause reactions

    i. Digestive disorders – diarrhoea and colicky pains.

    ii. Nervous disorders – hyperactivity, insomnia and irritability.

    iii. Respiratory problems – asthma, rhinitis and sinusitis.

    iv. Skin problems – hives, itching, rashes and swelling.

3. Risk Characterization describes the origin, magnitude, and uncertainties of estimates of the health risk. Considerations for evaluating the overall risk of using a food additive must include whether it has specific hazardous properties, a prediction of the likelihood of adverse effects based on exposure, and an estimation of the amount of exposure.

UNIT 4 IMPORTANT ISSUES IN FOOD SAFETY AND QUALITY

CONTENTS

4.1 Introduction

Food is a major determinant of health, nutritional status and productivity of the population. It is, therefore, essential that the food we consume is wholesome and safe. Unsafe food can lead to a large number of food-borne diseases. Food-borne illnesses do not only result in high mortality rate but can damage trade and tourism, lead to loss of earnings, unemployment and litigation. Thus they can impede economic growth, and therefore food safety and quality have gained worldwide significance.

4.2 Learning Outcomes

On completion of this unit, you should be able to:

- discuss the significance of issues relating to food safety and quality
- discuss the basic concepts of food safety and quality with regards to toxicity, hazards, infection, poisoning and intoxication
- discuss the basic concepts of food safety and quality with reference to standards by CAC, IOS and WTO
- discuss the basic concepts of food safety and quality as they relate to food safety management systems

Food safety and quality are important at the home level, but are critical in large scale food production and processing, and also where food is freshly prepared and served. In the past, many foods were processed at home. Advancement in technology and processing, higher per capita incomes and better purchasing power as well as increased consumer demand have led to a variety of processed foods, food for health / functional foods being manufactured. Safety of such foods needs to be assessed.

4.3 Significance of Food Safety and Quality

The quality of food stuff, raw as well as processed, is of public health concern and must be addressed. In the past decade, safety challenges have been faced globally and as indicated by the World Trade Organization (WTO), they have changed significantly and issues relating to food quality and food safety have gained tremendous importance.

- **World Trade Organization (WTO)**

Non-tariff agreement has provided greater access to world markets and opportunities to all countries to enter international trade. In this scenario, it has become essential for every country to protect the safety and quality of foods and also ensure that imported foods are of good quality and safe for consumption. It is also imperative for foods that are exported to other countries are safe and of good quality.

- **Significance:**

Effective food standards and control systems are required to protect food production within the country as well as to facilitate trade with other nations. All food manufacturers are required to meet the given standards of quality and safety, and hence the need to have their products regularly tested and regulated.

A number of factors are responsible for this:

Changing lifestyle: With fast changing lifestyles and eating habits, more people are eating outside their homes. In commercial settings, foods are prepared in bulk and are handled by many persons. Thus there are more chances of food getting contaminated. Furthermore, food items are prepared many hours in advance, and may get spoilt if not stored appropriately.

Assorted processed and packaged foods: There are many processed and packaged foods. Safety of these foods is important.

Pre-packaged food additives: Spices, condiments and oilseeds were processed at home in former times and purity of these were not a concern. In today's world, pre-packaged individual spices, condiments, spice powders and mixes are in demand, especially in cities and metros. Quality of even raw food stuff, besides processed foods, is of public health concern and must be addressed.

Bulk food transportation: Logistics governing transport of bulk food is complex and there is a long gap between processing and consumption. Thus risk assessment and safety management during mass production and mass distribution is critical.

Food-borne pathogens: Microbial adaptations, antibiotic resistance, altered human susceptibility and international travelling have all contributed to increasing incidence of food-borne microbial diseases. Nearly half of all known food-borne pathogens have been discovered during the past 25-30 years. There are still many food borne illnesses of unknown etiology. This is an issue of global public health concern and there is a need to detect, identify and recognise emerging pathogens and establish active surveillance networks, nationally and internationally.

Pollution: Pollution in atmosphere, soil and water, including use of pesticides in agriculture, bring their share of contaminants. Also, use of additives such as preservatives, colourants, flavouring agents and other substances such as stabilisers makes the analysis of food for various components — both nutrients and contaminants—imperative.

Owing to the above factors, there is a growing concern for safe, wholesome and nutritious foods in a highly dynamic food business in the global environment. Hence there is need for food safety management systems

Self-Assessment Exercises 1

1. Enumerate the factors necessitating the regular testing of food products safety and quality
2. What is the goal of food safety testing?

4.4 Basic Concepts

4.4.1 Food safety means assurance that food is acceptable for human consumption according to its intended use. An understanding of food safety is improved by defining two other concepts — toxicity and hazard.

Toxicity and Hazard: Toxicity is the capacity of a substance to produce harm or injury of any kind under any conditions. Hazard is the relative probability that harm or injury will result when a substance is not used in a prescribed manner and quantity. Hazards can be physical, chemical and biological causing harmful/adverse effects on the health of consumers.

A physical hazard is any physical material not normally found in food, which causes illness or injury. They include wood, stones, parts of pests, hair, etc.

Fig.1: Physical Hazards in Food

Chemical hazards are chemicals or deleterious substances which may be intentionally or un-intentionally added to foods. This category of hazards includes pesticides, chemical residues, toxic metals, polychlorinated biphenyls (PCBs), preservatives, food colours and other additives

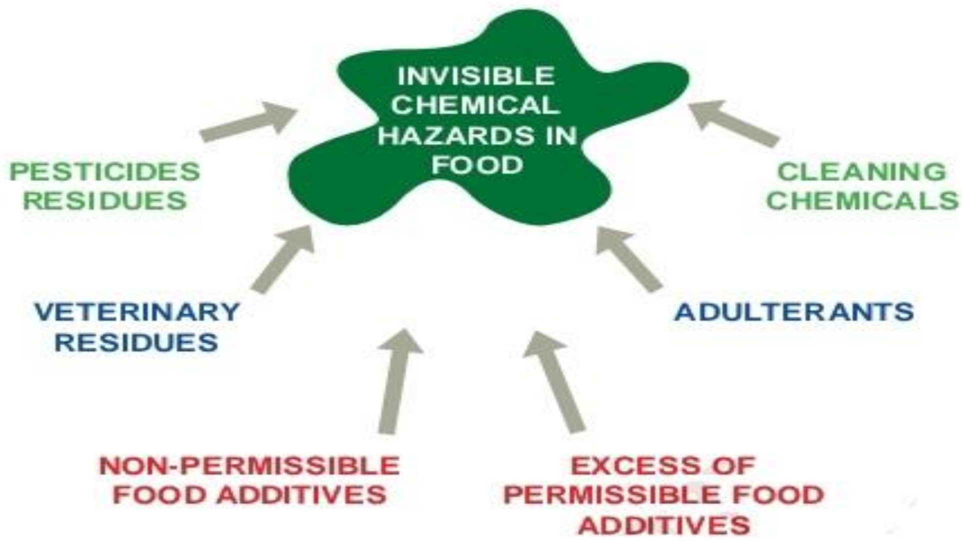


Fig. 2: Chemical Hazards in Food

Biological hazards are living things, including microbiological organisms (Fig.3 and 4). Micro-organisms are associated with food and cause diseases. They are called food-borne pathogens and are of two types, causing infections and poisoning.

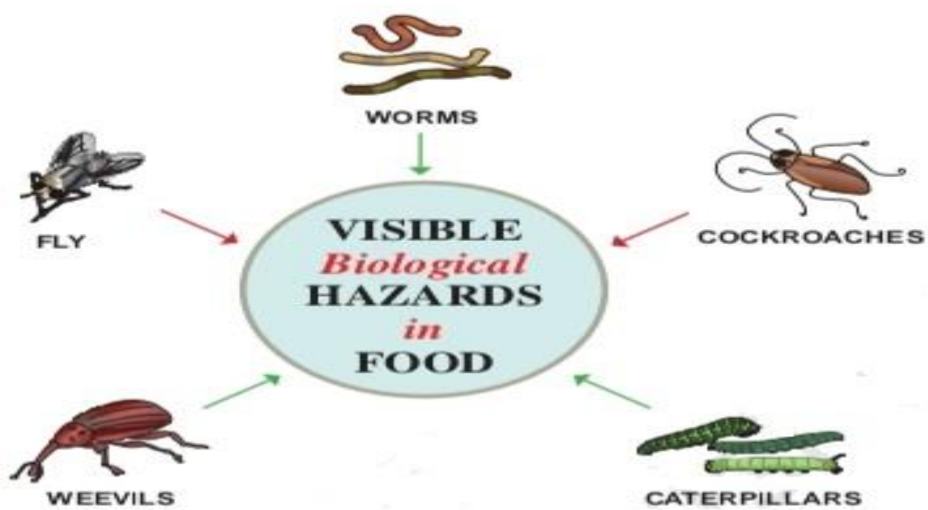


Fig. 3: Visible Biological Hazards in Food

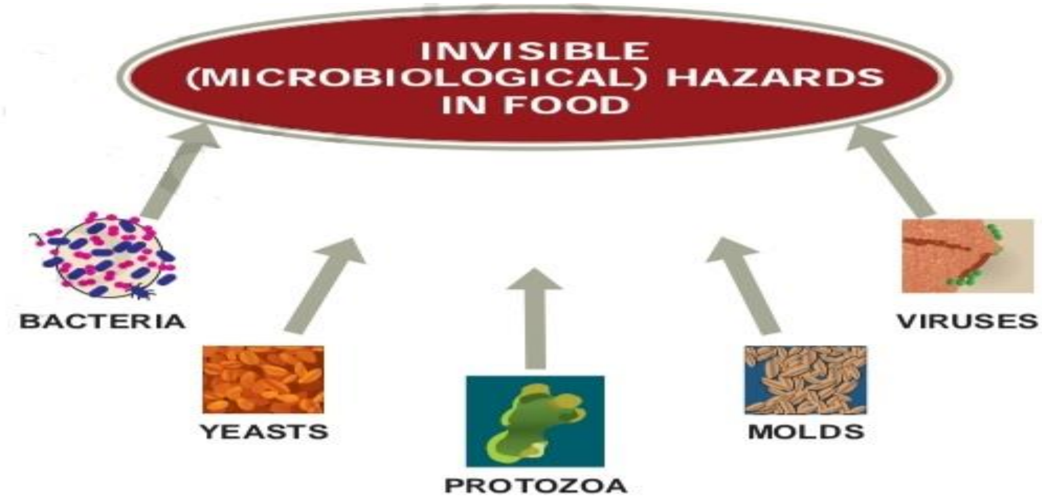


Fig. 4: Invisible Biological Hazards in Food

Food infection/ food poisoning results from ingestion of live pathogenic organisms which multiply in the body and cause disease. Salmonella is a classic example.

Food intoxication: Some bacteria produce harmful toxins which are present in food even if pathogens have been killed. Organisms produce toxins when the food has not been hot enough or cold enough. Toxins in food cannot be detected by smell, appearance or taste. Hence foods which smell and appear good are not necessarily safe. In addition to this, food can be infested by pests and insects (Fig.5).

Fig.5: Infestation of Food

Among the various hazards, biological hazards are an important cause of food-borne illnesses. In spite of all the efforts in the area of food safety, microbial food-borne pathogens are still a serious concern and new pathogens continue to emerge.

In the context of food safety, it is important to understand the terms contamination and adulteration.

- **Contamination:** It is the presence of harmful, or objectionable foreign substances in food such as chemicals, micro-organisms, and dilutants before/during or after processing or storage.
- **Adulteration:** Food adulteration is the process in which the quality of food is lowered either by the addition of inferior quality material or by extraction of valuable ingredient. It not only includes the intentional addition or substitution of the substances but biological and chemical contamination during the period of growth, storage, processing, transport and distribution of the food products. It is also responsible for lowering or degradation of the quality of food products.
- **Adulterants:** are those substances which are used for making the food products unsafe for human consumption.

Food Quality: The term food quality refers to attributes that influence a product's value to consumers. This includes both negative attributes such as spoilage, contamination, adulteration, food safety hazards as well as positive attributes such as colour, flavour, texture. It is therefore a holistic concept integrating factors such as nutritional traits, sensorial properties (colour, texture, shape, appearance, taste, flavour, and odour), social considerations, safety. Safety is a preliminary attribute and precursor of quality. In order to ensure that foods are safe and of good quality, across the world various governments and international bodies have laid down food standards that manufacturers/suppliers are expected to adhere to.

Thus, all food service providers (those involved at all stages of pre-preparation and preparation/processing, packaging and service) should adhere to good manufacturing practices and ensure food safety. Salient points to be borne in mind are:

- Quality of raw materials and water
- Cleanliness — of the premises, personnel, equipment, food preparation and storage and serving areas
- Storage of food at appropriate temperature
- Food hygiene
- Good service practices.

4.4.2 Food Standards

Effective food standards and control systems are required to integrate quality into every aspect of food production and service, to ensure the supply of hygienic, wholesome food as well as to facilitate trade within and between nations.

*** International Organisations and Agreements in the Area of Food Standards, Quality, Research and Trade**

Since ancient times, governing authorities the world over, have made attempts to develop and implement food standards in order to protect health of consumers and prevent dishonest practices in the sale of food. There have been several international organisations and agreements which have played a role in enhancing food safety, quality and security, facilitating research and trade. The major organisations which are playing key roles are Codex Alimentarius

Commission (CAC), International Organisation for Standardisation (ISO) and World Trade Organisation (WTO).

*** Codex Alimentarius Commission (**CAC) is an intergovernmental body formed with the objective of establishing international standards to protect the health of the consumers and facilitate food and agricultural trade. In 2017, the membership of Codex was 187 member countries and one Member Organisation (European Community) respectively. CAC has become the single most important international reference point for developments associated with food standards. The document published by the CAC is Codex Alimentarius, which means ‘Food Code’ and is a collection of internationally adopted Food Standards. The document includes Standards, Codes of Practice, Guidelines and other recommendations in order to protect consumers and ensure fair practices in food trade. Different countries use Codex Standards to develop national standards.

*** International Organisation for Standardisation (ISO)** is a worldwide, non-governmental federation of national standards bodies (ISO member bodies). The mission of ISO is to promote the development of standardisation and related activities in the world with a view to facilitate the international exchange of goods and services, and to develop cooperation in the spheres of intellectual, scientific, technological and economic activity. The work done by ISO results in international agreements which are published as International Standards Organization. ISO 9000 is an international reference for quality requirements. It is concerned with “Quality Management” of an organisation. Adoption of these standards is voluntary.

*** World Trade Organisation (WTO)** was established in 1995. The main objective of WTO is to help trade flow smoothly, freely, fairly and predictably, by administering trade agreements, settling trade disputes, assisting countries on trade policy issues. The WTO Agreement covers goods, services and intellectual property.

4.4.3 Food Safety Management Systems

Over the years, issues related to food safety and quality have gone beyond just the avoidance of food-borne pathogens, chemical toxicants and other hazards. A food hazard can enter/come into the food at any stage of the food chain, therefore, adequate control through out the food chain is essential. Food safety and quality can be ensured through Good Manufacturing Practices (GMP), Good Handling Practices (GHP) and Hazard Analysis Critical Control Points (HACCP)

* **Good Manufacturing Practices (GMP)** are a part of quality assurance to ensure that manufacturers/processors take proactive steps to ensure that their products are safe. It enables them to minimise or eliminate contamination and false labelling, thereby protecting the consumer from being misled and helping in purchasing products that are not harmful. GMP is a good business tool that helps to refine compliance and performance by the manufacturers/producers.

* **Good Handling Practices (GHP)** indicate a comprehensive approach from the farm to the store or consumer, in order to identify potential sources of risk and indicate what steps and procedures are taken to minimise the risk of contamination. It ensures that all persons who handle food have good hygiene practices.

* **Hazard Analysis Critical Control Point (HACCP)** is a means of providing assurance about safety of food. HACCP is an approach to food manufacture and storage in which raw materials and each individual step in a specific process are considered in detail and evaluated for its potential to contribute to the development of pathogenic microorganisms or other food hazards.

It involves identification of hazards, assessment of chances of occurrence of hazards during each step /stage in the food chain — raw material procurement, manufacturing, distribution, usage of food products and defining measures for hazard(s) control.

Self-Assessment Exercises 2

1. State some (i) food safety procedures and policies (ii) food quality attributes you know
2. What is food adulteration?

4.5 Summary

The significance of various issues relating to food safety and quality were highlighted in this unit. Basic concepts of food toxicity, food hazards, food poisoning and food intoxication arising from physical, chemical and biological sources have been explained. Food standards, quality, research and trade, as regulated and controlled by international regulatory bodies such as CAC, WTO and ISO, are important to ensure the protection and safety of consumers. Food Safety Management Systems **a**re to ensure food safety and quality through good manufacturing practices (GMP), good handling practices (GHP) and hazard analysis critical control points (HACCP).

In this unit we have learnt the; Significance of Food Safety and Quality with respect to World Trade Organization (WTO) and other International Regulatory Bodies' standards, Basic Concepts with reference to food safety, food standards and food safety management systems have also been explained.

4.6 Glossary

Additive: A substance added to something in small quantities to improve or preserve it

Agent: Is something that produces or is capable of producing an effect

Approval: An act of officially accepting or allowing something

Amino acids: They are organic compounds composed mainly of nitrogen, carbon, hydrogen, and oxygen.

Anti: It is opposed to or against

Antimicrobial: A substance produced by one living organism that kills or inhibits the growth of another.

Antioxidants: They are substances that can prevent or slow damage to cells caused by free radicals, unstable molecules that the body produces as a reaction to environmental and other pressures.

Assessment: The act of judging or deciding the amount, value, quality, or importance of something, or the judgment or decision that is made

Assorted: Consisting of different or various kinds

Benefit: Something that produces good or helpful results or effects or that promotes well-being

Browning: Is the process of food turning brown due to the chemical reactions that take place within.

Challenge: Anything, as a demanding task, that calls for special effort or dedication.

Colouring: To change the colour of (something) by painting, dyeing, or shading it

Control: It is either power or influence applied to the complete and successful direction or manipulation of persons or things

Documentation: Is any communicable material that is used to describe, explain or instruct regarding some attributes of an object, system or procedure, such as its parts, assembly, installation, maintenance and use.

Dose: An amount of something

Effective: Adequate to accomplish a purpose, or that produce the intended or expected result

Exposure: The fact of experiencing something or being affected by it because of being in a particular situation or place

Fibre: Is the portion of plant-derived food that cannot be completely broken down by human digestive enzymes

Flavoring: Is a substance that gives another substance taste, altering the characteristics of the solute, causing it to become sweet, sour, tangy, etc.

Food: Any nutritious substance that people or animals eat or drink or that plants absorb in order to maintain life and growth.

Foodborne: Caused by food contaminated with pathogenic microorganisms or toxic substances

Food quality: Represents the sum of all properties and attributes of a food item that are acceptable to the customer.

Food safety: It refers to the proper handling, cooking, and preservation of food in order to protect people from foodborne illnesses caused by microbes such as bacteria, fungi, parasites, and viruses.

Food standard: A set of criteria that a food must meet if it is to be suitable for human consumption, such as source, composition, appearance, freshness, permissible additives, and maximum bacterial content.

Function: The action for which a person or thing is specially fitted or used or for which a thing exists

Hazard: An unavoidable danger or risk, even though often foreseeable

Inspection: An official check done on something to see that it is of the right standard or quality, or whether it is safe to use

Intake: An amount of food, air, or another substance taken into the body

Labeling: To attach a piece of paper or other material that has information about an object to that object

Mineral: It is a chemical element required as an essential nutrient by organisms to perform functions necessary for life

Miscellaneous: Consisting of a mixture of various things that are not necessarily connected with each other

Nutrition: It is the biochemical and physiological process by which an organism uses food to support its life.

Nutritious: Containing many of the substances needed for life and growth

Pathogens: A bacterium, virus, or other microorganism that can cause disease.

Preservative: It is a substance or a chemical that is added to products such as food products, beverages, pharmaceutical drugs, paints, biological samples, cosmetics, wood, and many other products to prevent decomposition by microbial growth or by undesirable chemical changes

Quantity: The aspect or property of anything that can be measured, weighed, counted, etc

Regulate: To control an activity or process by rules or a system

Regulations: Are rules made by a government or other authority in order to control the way something is done or the way people behave.

Response: Is a reaction to a question, experience, or some other type of stimulus.

Risk: A probability or threat of damage, injury, loss, or any other negative occurrence that is caused by external or internal vulnerabilities, and that may be avoided through preemptive action

Safe: Protected from or not exposed to danger or risk; not likely to be harmed or lost

Strategy: A carefully developed plan or method for achieving a goal or the skill in developing and undertaking such a plan or method

Texture: Refers to those qualities of a food that can be felt with the fingers, tongue, palate, or teeth

Toxicant: Is an agent that causes an adverse effect or response in a biological system, seriously damaging its structure or function or producing death.

Usage: Is the degree to which something is used or the way in which it is used

Vitamin: It is an organic molecule that is an essential micronutrient that an organism needs in small quantities for the proper functioning of its metabolism.

4.7 References/Further Readings

Food Safety and Standards Authority of India. Ministry of Health and Family Welfare, Government of india.

Insel, P., Turner, E.Rr., Ross, D. Nutrition, 3rd edition. American Dietetic Association.

Jood, S. and N. Khetarpaul, 1991. Food preservation. Agrotech Publishing Academy. Jaipur.
lehe 106.pdf

Manay, S. N. and M. Shadaksharawamy, 2001. (eds) Foods, facts and principles. 3rd edition, New Age International. New Delhi.

Rao, J. P. 2006. Nutrition and food science. Aavishkar publishers, distributors, Jaipur.

Satarkar, A. 2008. Food science and nutrition. ABD Publishers. Jaipur.

Sethi, M. 2008. Institutional food management. New Age Publishers. New Delhi.

Subbulakshmi, G. And S. A. Udipi, 2006. Food processing and preservation. New Age Publishers, New Delhi.

Unicef state of the world's children. Report.

Unicef website www.unicef.org

Wadhwa, A. and S. Sharma, 2003. Nutrition in the community. A textbook. Elite publishing house pvt. Ltd.

WHO website www. whoindia.org, www.who.int

4.8 Possible Answers to Self-Assessment Exercises

Self-Assessment Exercises 1

1. The factors are changing lifestyle, assorted processed and packaged foods, pre-packaged food additives, bulk food transportation, food-borne pathogens, and pollution
2. The main goal of conducting food safety testing is to analyze food products and determine if they are safe for consumption. Testing support the claim of food businesses regarding their compliance with food safety regulations and laws and that their operations are up to food safety standards. These activities are essential in providing the best and safest consumption experience and ensuring food quality. The requirements for conducting food safety testing highlight the importance of food safety.

Self-Assessment Exercises 2

1. (i) Safety procedures and policies:
    - i. Personal hygiene
    - ii. Personal presentation and preparation
    - iii. Pest control
    - iv. Waste management

v. Cleaning and sanitising

vi. Temperature control and measurement

vii. Food Safety hazard identification

(ii) Food Quality Attributes:

i. External factors such as appearance (size, colour, shape and consistency).

ii. Texture

iii. Flavour (odour and taste)

iv. Correct labelling with the ingredients, nutritional information and supplier/manufacturer details listed.

v. Products must be properly packaged and sealed.

vi. Ingredient standards are maintained.

vii. Food quality also deals with product traceability, should a recall of the food product be required.

2. Adulteration: Food adulteration is the process in which the quality of food is lowered either by the addition of inferior quality material or by extraction of valuable ingredient. It not only includes the intentional addition or substitution of the substances but biological and chemical contamination during the period of growth, storage, processing, transport and distribution of the food products. It is also responsible for lowering or degradation of the quality of food products.

MODULE 2

UNIT 1 NUTRITIVE ADDITIVES: VITAMINS 1

CONTENTS

1.1 Introduction

The term nutritional additives can be used to mean the addition of vitamins, minerals, amino acids, fatty acids as well as other pure chemical compounds to food in order to improve or maintain its nutritional quality. However, manufacturers soon discovered that along with an improvement in nutritional qualities, nutritional additives often provide functional qualities.

Vitamins are among the commonly used nutritional additives. Only small amounts of the vitamins are required in the diet to promote health. Vitamins A, D, E and K are called the fat-soluble vitamins, because they are soluble in organic solvents and are absorbed and transported in a manner similar to that of fats.

In this unit we shall study the fat-soluble vitamins as food additives with regards to their source, chemistry, units of requirement etc.

1.2 Learning Outcomes

On completion of this unit, you should be able to:

- discuss the vitamins: their types in terms of functions and solubility
- evaluate fat soluble vitamins such as Vitamin A, Carotenoids, Vitamin D, Vitamin E and Vitamin K with respect to their characteristics

1.3 Vitamins

Vitamins are organic compounds that facilitate a variety of biological processes. Since the body cannot manufacture vitamins, they must be obtained naturally from foods or added to foods. Fruits and vegetables are a veritable source of vitamins as depicted in fig. 1.

Fig. 1: Fruits and vegetables as a good source of vitamins

1.3.1 Types of vitamins: There are several types of vitamins. They are categorized according to their functions in the body of the organisms, including human beings. Consequently, we have vitamins A, B, C, D, E and K. They are also classified according to their solubility in either polar solvent (like water) or non-polar solvent (such as fats and oils).

Solubility of vitamins: Vitamins are classified as water soluble or fat soluble depending on their characteristics. Water soluble vitamins have high solubility in water but are poorly soluble in fats. They are not stored in body tissues in high amounts and excesses are generally excreted in urine. Examples of water soluble vitamins are vitamin C and many of the various series of vitamins that make up the vitamin B complex.

Fat soluble vitamins are linked with lipid metabolism and are generally insoluble or poorly soluble in water. Since fat soluble vitamins can be stored in the human body it is less important to have a daily supply of these vitamins. Excess amounts of fat soluble vitamins can, in some cases lead to toxic effects. The fat soluble vitamins are vitamins A, D, E, and K. Vitamins A, C, and E are also classed as antioxidants because they have the capacity to protect the body from free radicals.

Self-Assessment Exercises 1

1. What is a vitamin?
2. Which vitamins are water-soluble vitamins?

1.4 Fat Soluble Vitamins

1.4.1 Vitamin A: The beginning of the modern nutritional history of vitamin A started in 1913 with the recognition of a growth-stimulating factor in cod liver oil and butter. The active principal component of liver oil is vitamin A. Adequate intake of vitamin A is essential for normal vision, growth, cellular differentiation, reproduction and integrity of the immune system

* **Deficiency** of vitamin A is commonly seen as night blindness and/or dry and lustreless corneas. It is the major cause of blindness in the developing world. Inadequate amounts are also associated with protein-calorie malnutrition, low intake of fat, lipid malabsorption syndromes, and febrile diseases. Acute infections of childhood such as measles, respiratory infections and diarrhoea have also been associated with increased risk of developing vitamin A deficiency. Also of concern is the susceptibility of pregnant women to vitamin A depletion, because of increased demands, during pregnancy and altered dietary habits.

* **Units and requirements:** Vitamin A has been traditionally expressed in international units (IU). One IU is defined as the amount of vitamin A activity contained in 0.344 µg of all-trans-retinyl acetate, which is equivalent to 0.300 µg of all-trans-retinol. However, in 1965 IUs were replaced with the preferred measurement of retinol equivalents (RE), expressed in micrograms of retinol. This unit is defined as the amount of retinol plus the equivalent amount of retinol that can be obtained from the provitamin A carotenoids. Recommended dietary allowances (RDAs) have

been redefined based on age, body mass, metabolic activity, and special conditions such as pregnancy and lactation. The RDA for males of ages 11 to 51 currently is 1000 µg RE.

* **Source:** Preformed vitamin A is found in foods of animal origin, either in storage areas such as the liver or associated with the fat of milk and eggs.

Fig.1: Sources of Vitamin A

* **Commercial Forms:** Vitamin A is available in pure form by chemical synthesis as vitamin A palmitate or the acetate. Several different commercial preparations are available for fortification: 250 CWS, 250 S, 250 SD, 500, Emulsified RP and Oil.

* **Toxicity:** In amounts several times higher than the recommended dietary allowance, vitamin A will cause toxicity in humans. With children, signs and symptoms of acute vitamin A toxicity include anorexia, bulging fontanelles, drowsiness, increased intracranial pressure, irritability, and vomiting. Signs and symptoms in adults include abdominal pain, anorexia, blurred vision, drowsiness. Toxicity is of greatest concern in persons with compromised liver function, children, and pregnant women. Symptoms disappear when excess intakes are discontinued.

1.4.2 Carotenoids: Although not vitamins per se, carotenoids serve as a precursor to provide vitamin A. This provitamin is converted by the body to vitamin A with various degrees of efficiency. The yellow, red, orange, and violet pigments of carotenoids are largely responsible for the colour of many vegetables and fruits. Carotenoids function not only as colour and nutrient compounds but also as antioxidants. Although carotenoids may have favorable effects and may reduce the risk of some diseases, since carotenoids are not essential nutrients there is no need to use the term ‘‘carotenoid deficiency’’.

* **Units and requirements:** In 1965, an expert committee decided to abandon the international unit measurement for vitamin A in favour of retinol equivalents (14), a purely dietary concept defined as the amount of retinol plus the equivalent amount of retinol that can be obtained from the provitamin A carotenoids. There is no separate RDA listing for carotenoids.

* **Sources:** Provitamin A carotenoids are synthesized exclusively by higher plants and photosynthetic microorganisms. Carotenoids are mainly obtained from plant sources such as carrots, green leafy vegetables, spinach, oranges, and tomatoes. Animal sources include calf liver, whole milk, butter, cheddar cheese, and eggs.

* **Commercial forms:** Beta carotene is available as red crystals or crystalline powder (CAS: 7236-40-7) (15). Carotenoids are highly sensitive to loss by oxidation and should be protected with appropriate packing materials and storage conditions. Most of the beta carotene available commercially is of synthetic origin. These synthetic compounds are identical in every way, both chemically and biologically, to substances isolated from natural sources.

* **Toxicity:** A yellow, jaundicelike coloration of the skin is evident in individuals who routinely ingest excessively large amounts of carotenoids. This condition may be especially noticeable on the nasolabial folds, the fat pads of the palms of the hands, and the fatty areas of the soles of the feet. However, this condition is completely benign and will slowly disappear once an excess of carotenoid rich foods are removed from the diet.

1.4.3 Vitamin D: The primary function of vitamin D is to maintain serum calcium and phosphorus concentrations in a range that supports cellular processes, neuromuscular function, and bone ossification. Vitamin D was found to prevent and cure rickets, a disease associated with malformation of bones. Individuals in societies where custom requires complete clothing coverage, as well as individuals in areas where sunlight days are limited, may be at greater risk for vitamin D deficiency.

* **Chemistry:** There are two common forms of vitamin D. They are ergocalciferol, known as Vitamin D2, and cholecalciferol, known as vitamin D3. Precursors of vitamin D2 are found in sterol fractions in both animal and plant tissues. Vitamin D3 is produced by the action of sunlight on the skin.

* **Units and requirements:** The 1997–1998 Dietary Reference Intakes recommend adequate intake (AI) for vitamin D at 5 µg from infancy to age 50, 10 µg for ages 51–70, and 15 µg for over the age of 70.

* **Sources:** Food sources are mainly animal products in unfortified foods. Saltwater fish such as herring, salmon, and sardines and fish liver oils are good sources. Beginning in the 1930s, milk was fortified with 400 IU (10 µg) of vitamin D2 per quart. Other major sources of fortified foods include butter, margarine, cereals, and chocolate mixes. Vitamin D can be produced in the skin after exposure to sunlight.

Fig.2: Sources of Vitamin D

* **Toxicity:** Excessive amounts of vitamin D are not normal unless there is excessive use of supplemental vitamins. Toxicity includes hypercalcemia, hypercalciuria, anorexia, nausea, vomiting, thirst, polyuria, muscular weakness, joint pains, diffuse demineralization of bones, and general disorientation. Excesses of supplemental vitamin D can lead to massive stimulation of intestinal calcium absorption and bone calcium resorption and ultimately soft tissue calcification and kidney stones. Left unchecked, death will eventually occur.

1.4.4 Vitamin E: Vitamin E is the major lipid-soluble, membrane-localized antioxidant in humans. It acts in foods to prevent the peroxidation of polyunsaturated fatty acids. In the gut, it enhances the activity of vitamin A by preventing oxidation in the intestinal tract. Vitamin E, at the cellular level, also appears to protect cellular and subcellular membrances from deterioration by scavenging free radicals that contain oxygen. Cell-mediated immunity in healthy elderly subjects treated with 800 mg of vitamin E in the form of DL-α-tocopheryl acetate was found to be significantly improved.

*** Deficiencies:** Sources of dietary vitamin E are widely available and as a result deficiencies are relatively uncommon. Deficiencies that do occur are usually associated with malabsorption or lipid transport abnormalities.

* **Units and requirements:** Vitamin E has traditionally been expressed as international units. By international agreement, the 1989 RDAs are listed by milligrams of α-tocopherol equivalents. One milligram of D-α-tocopherol is equivalent to 1.49 IU. The recommended intake of the different forms of vitamin E depends in part on the bioactivity of each form as well as the amount of polyunsaturated fatty acids (PUFAs) consumed. Since intake of PUFAs varies with individuals, the amount of vitamin E needed to balance the minimum requirement for PUFAs is not known, but is estimated to be 3 to 4 mg α-tocopherol (4.5 to 6.0 IU) per day.

* **Sources:** The richest sources of vitamin E are vegetable oils—including soy bean, corn, cottonseed, and safflower—and products made from these oils such as margarine, shortening, and mayonnaise, as well as wheat germ, nuts, and other grains. Meats, fish, animal fat, and most fruits and vegetables contain little vitamin E.

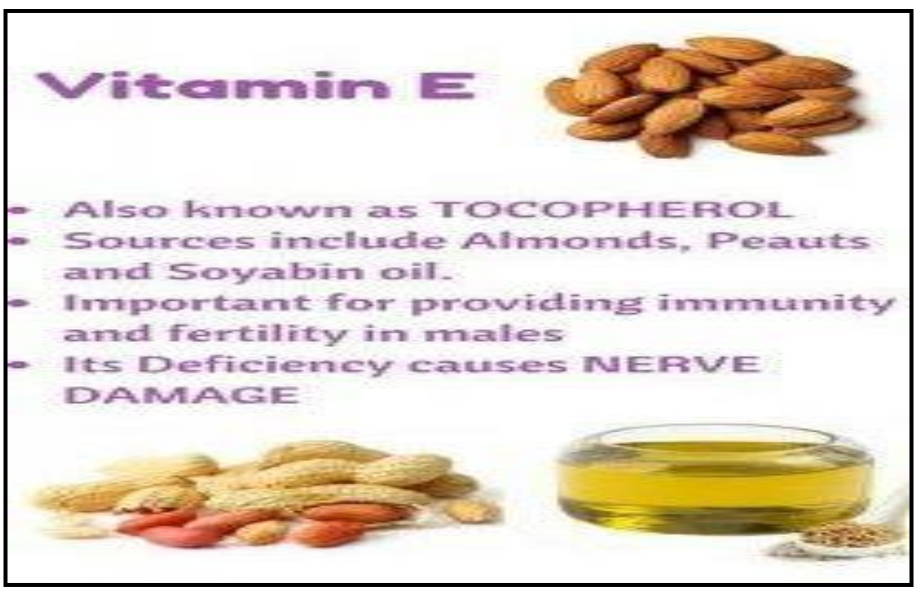


Fig.3: Sources of Vitamin E

* **Commercial Forms:** DL-α-Tocopherol, D-α-Tocopherol concentrate, Tocopherols concentrate, all mixed together. Other forms are D-α-Tocopheryl acetate, DL-α-Tocopheryl acetate, D-α-Tocopheryl acetate concentrate and D-α-Tocopheryl acid succinate.

* **Toxicity:** Vitamin E is relatively nontoxic. However, large intakes of vitamin E might interfere with absorption of Vitamin A and vitamin K. Doses necessary to elicit toxicity far exceed those necessary for nutritional sufficiency.

1.4.5 Vitamin K: Vitamin K functions in the liver as an essential cofactor for carboxylase. This enzyme converts specific glutamic acid residues of precursor proteins to a new amino acid called gammacarboxyglutamic acid (Gla). Vitamin K–dependent blood clotting factor prothrombin (factor II) and factor VII, IX, and X are included in the proteins. Vitamin K plays a crucial role in blood clotting activities. Vitamin K is not only associated with coagulation, but also with additional functions in bone, kidney and possibly other tissues.

* **Deficiencies:** Deficiencies in vitamin K status are relatively uncommon. However, since newborns do not have the necessary menaquinones, due to poor vitamin K placenta transfer, administration of vitamin K to newborns has become common practice.

* **Units and requirements:** The 1989 RDA for vitamin K for men 25 and older is 80 µg, and for women 25 and older is 65 µg. Recommended intake for infants during the first 6 months is 5 µg phylloquinone/ day, and for 6 to 12 months is 10 µg phylloquinone/day.

* **Sources:** Green leafy vegetables, especially broccoli, cabbage, turnip greens, and lettuce, have large amounts of vitamin K. Other vegetables, fruits, cereals, dairy products, eggs, and meat contain smaller amounts. A significant amount of vitamin K is formed by the bacterial flora of the human lower intestinal tract.

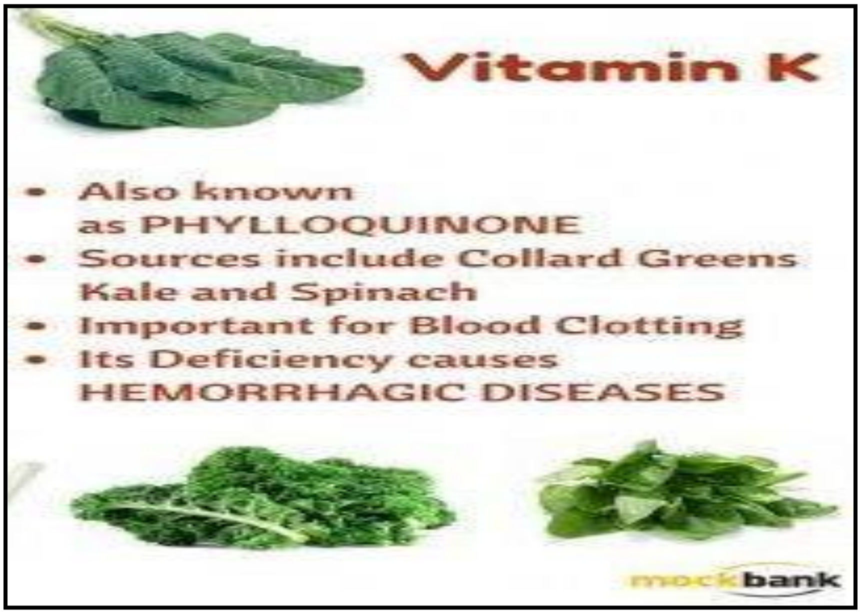


Fig.4: Sources of Vitamin K

* **Commercial forms:** Vitamin K (CAS: 84-80-0) is a clear, yellow to amber, very viscous liquid that is stable in air but decomposes when exposed to sunlight.

* **Toxicity:** There is no known toxicity associated with the administration of high doses of vitamin K1. However, administration of vitamin K3 to infants is associated with hemolyticanemia and liver toxicity. Vitamin K1 is now prescribed to prevent hemorrhagic disease in newborns.

Self-Assessment Exercises 2

1. Which vitamins are in fat-soluble?
2. What is the best source of fat-soluble vitamins?

1.5 Summary

Food additives are substances that are added to food in order to improve or maintain its nutritional quality. Vitamins are a set of vital food additives which the body needs in order to attain and maintain good health. Deficiency of any of the vitamins results in a condition of ill-health. Fruits and vegetables are a veritable source of vitamins. The various types of vitamins are vitamins A, B, C, D, E and K, among which A, D, E and K are readily soluble in lipids (i.e. fats and oils) but insoluble in water. The large varieties of vitamin B complex and vitamin C are readily soluble in water but insoluble in lipids. In this unit, our study was focused on the fat soluble vitamins.

In this unit you have learnt about; the fat soluble vitamins with reference to their deficiencies, units and requirements, sources, commercial forms and toxicity.

1.6 References/Further Readings

Binkley, N. C., Suttie, J. W. 1995. Vitamin K nutrition and osteoporosis. J. Nutr. 125:1812–1821. 36. Suttie, J. W. 1996. Vitamin K. In: Present Knowledge in Nutrition, 7th ed., Ziegler, E. E., Filer, L. J. (Eds.). ILSI Press, Washington, D.C., pp. 137–145.

Committee on Food Chemical Codex Food & Nutrition Board. 1996. Food Chemical Codex, 4th ed. Institute of Medicine, National Academy of Sciences. National Academy Press, Washington, D.C. Vitamin K

Committee on Food Chemicals Codex Food & Nutrition Board. 1996. Food Chemical Codex, 4th ed. Institute of Medicine, National Academy of Sciences. National Academy Press, Washington, D.C. Vitamin D

Duitsman, P. K., Cook, L. R., Tanumihardjo, S. A., Olson, J. A. 1995. Vitamin A inadequacy in socioeconomically disadvantaged pregnant Iowan women as assessed by the modified relative dose response (MRDR) test. Nutr. Res. 15:1263–1276.

FAO. 1996. Food fortification technology and quality control. FAO technical meeting, Rome. FAO Food and Nutrition Paper 60.

Ferland, G., Sadowski, J. A., O'Brien, M. E. 1993. Dietary induced subclinical vitamin K deficiency in normal human subjects. J. Clin. Invest. 91:1761–1768.

Food & Nutrition Board. 1998. Dietary Reference Intakes. National Academy Press, Washington, D.C.

Food and Nutrition Board. 1989. Recommended Dietary Allowances, 10th ed., National Academy Press, Washington, D.C.

Norman, A. W. 1996. Vitamin D. In: Present Knowledge in Nutrition, 7th ed., Ziegler, E. E., Filer, L. J., Jr. (Eds.). ILSI Press, Washington, D.C., pp. 120–129. Vitamin E

Olson, J. A. 1994. Vitamin A, retinoids, and carotenoids. In: M. E. Shils, J. A. Olson, M. Shike (Eds.), Modern Nutrition in Health and Disease, 8th ed., Shils, M. E., Olson, J. A., Shike, M. (Eds.). Williams & Wilkins, Baltimore, pp. 287–307.

Sokol, R. J. 1996. Vitamin E. In: Present Knowledge in Nutrition, 7th ed., Ziegler, E. E., Filer, L. J., Jr. (Eds). ILSI Press, Washington, D.C., pp. 130–136.

1.7 Possible Answers to Self-Assessment Exercises

Self-Assessment Exercises 1

1. A vitamin is an organic molecule (or a set of molecules closely related chemically, i.e. vitamers) that is an essential micronutrient that an organism needs in small quantities for the proper functioning of its metabolism. Essential nutrients cannot be synthesized in the organism, either at all or not in sufficient quantities, and therefore must be obtained through the diet.
2. The important water-soluble vitamins are vitamin C and the collection of B vitamins, including: B1 (thiamin), B2 (riboflavin), B3 (niacin), B4 (pantothenic acid), B6 (pyridoxine), B7 (biotin), B9 (folic acid or folate), B12 (cobalamin).

Self-Assessment Exercises 2

1. Fat-soluble vitamins are absorbed along with fats in the diet and are stored in the body's fatty tissue and in the liver. They are found in many plant and animal foods and in dietary supplements. Vitamins A, D, E, and K are fat-soluble.
2. The best dietary sources are fatty fish and fish oil, but mushrooms that have been exposed to ultraviolet light may also contain significant amounts. In addition, dairy products and margarine often come with added vitamin D.

MODULE 2

UNIT 2 NUTRITIVE ADDITIVES - VITAMINS I1

CONTENTS

2.1 Introduction

Water soluble vitamins are vitamins which dissolve in water and readily absorbed into tissues for immediate use. Because they are not stored in the body, they need to be replenished regularly in our diets. They include the B- complex vitamins and vitamin C.

In this unit we shall learn about the water soluble vitamins with reference to sources, requirements, deficiencies commercial forms and toxicity.

2.2 Learning Outcomes

On completion of this unit, you should be able to:

- discuss water soluble vitamins such as Vitamin C, Thiamin, Riboflavin, Niacin, Vitamin B6, Pantothenic acid, Folate, Vitamin B12, Biotin, Choline and Inositol with respect to their deficiencies, units and requirement, source, commercial form and toxicity.

2.3 Water Soluble Vitamins

2.3.1 Vitamin C: Vitamin C, or ascorbic acid, has many functions as either a coenzyme or cofactor. Because of its ease of losing or taking on hydrogen, it is essential in body metabolism. It is well recognized for its role in enhancing the absorption of iron. Vitamin C maintains the integrity of blood vessels.

*** Deficiency:** Scurvy is a disease condition that arises due to vitamin C deficiency in the body. Its discovery and identification was as a result of this condition of ill-health among sailors who did not eat fresh fruits and vegetables in their vouyages of many days at sea.

*** Units and Requirements:** The current RDA is 60 mg/day for adults, based on preventing signs and symptoms of scurvy and to provide adequate reserves. The 1989 RDA is based, partly, on the concept that urinary excretion of vitamin C indicates that body stores are near saturation. During lactation, the requirement for vitamin C is increased 50% or above. **sources:** The best sources of vitamin C are fruits and vegetables, preferably when they are acidic and fresh. These sources include citrus fruits, raw leafy vegetables, tomatoes, broccoli, strawberries, cantaloupe, cabbage and green peppers.

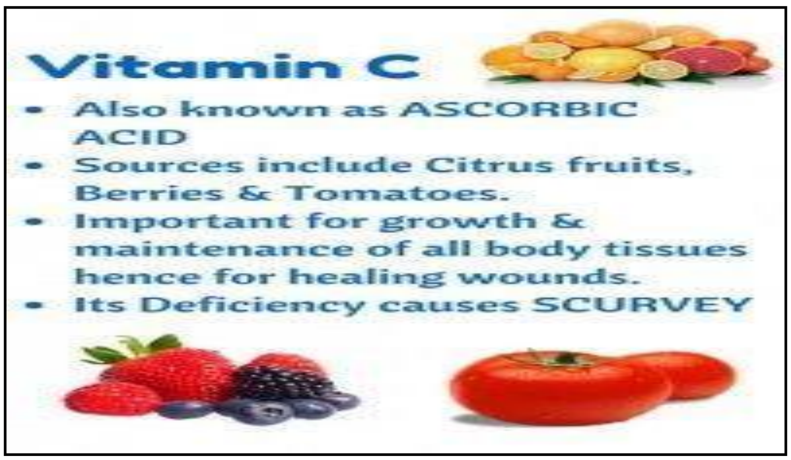


Fig.1: Sources of Vitamin C

*** Commercial forms:** l-Ascorbic acid (CAS: 50-81-7) is white or slightly yellow crystals or powder. It gradually darkens on exposure to light but is readily stable in air, when dry, and it rapidly deteriorates in solution in the presence of air. It is stored in air-tight light-resistant containers.

*** Toxicity:** Since vitamin C is one of the most commonly used supplements, excessive intake may occur. Symptoms may include diarrhea, abdominal bloating, iron over-absorption, nausea and kidney stones.

2.3.2 Thiamine: Thiamin, also called **vitamin B1**, is essential in energy transformation and membrane and nerve conduction as well as in the synthesis of pentoses and the reduced coenzyme form of niacin.

*** Deficiency:** Historically, thiamin has been known as the vitamin which prevents beriberi. Severe thiamin deficiency in humans leads to impairment of the auditory and visual pathways in the brain stem as well as impairment of the endocrine pancreas and the heart. In addition, clinical features of thiamin deficiency experienced by the chronic alcoholic includes ataxia and altered memory and alcoholic peripheral neuropathy.

*** Sources:** Food sources include meat, fish, whole cereal grains, fortified cereal and bakery products, nuts, legumes, eggs, yeast, fruits, and vegetables.

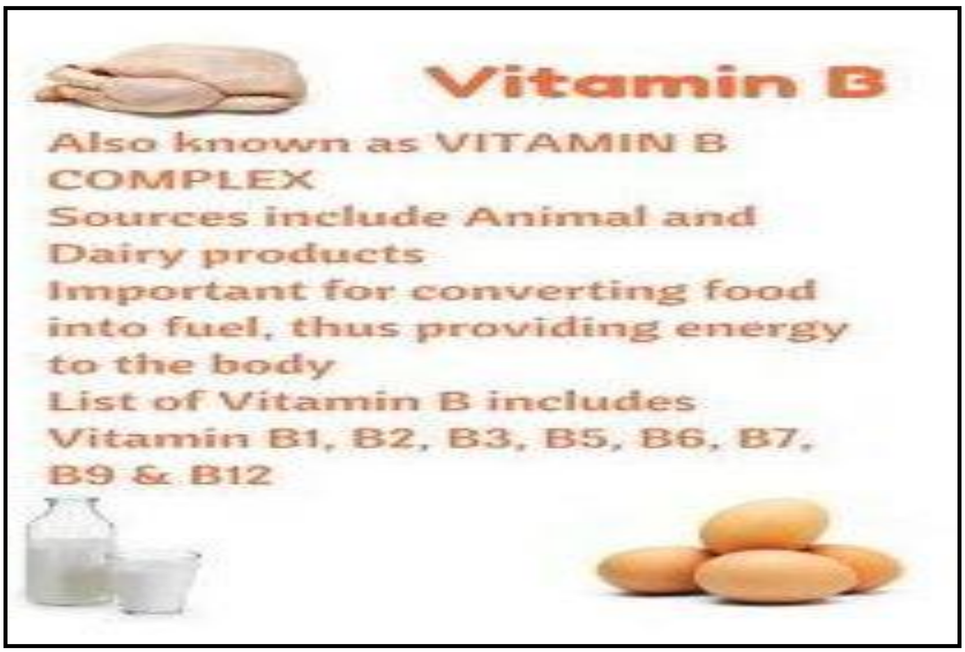


Fig.2: Sources of Vitamin B

*** Commercial Forms:** Thiamine Mononitrate (CAS: 532-43-4) is available as white to yellowish white crystals, or crystalline powder, usually having a slight characteristic odour. It is slightly soluble in alcohol and in chloroform. Thiamine Mononitrate should be stored in tight, light-resistant containers. Thiamin hydrochloride (CAS: 67-03-8) is also available as white to yellowish-white crystals or crystalline powder.

*** Toxicity:** Even in high oral doses, thiamin has been found to have no toxic effect other than possibly gastric upset.

2.3.3 Riboflavin: This is also called **vitamin B2.** It is another very important component of the vitamin B complex group of molecules.

*** Deficiencies** of riboflavin are usually in combination with deficiencies of other water soluble vitamins. Intake of riboflavin must be low for several months in order for signs of its deficiency to develop. Pellagra-like symptoms, including skin lesions around the mouth, nose and ears, occur when there is a riboflavin deficiency.

*** Units and Requirements:** The RDA values for riboflavin are given in milligrams. The 1997–1998 Dietary Reference Intakes ranges from 0.3 mg for infants to 1.1 mg for adult females and 1.3 mg for adult males.

*** Sources:** Riboflavin is widely distributed in small amounts. The best sources are milk, cheddar cheese and cottage cheese. Other good sources include eggs, lean meats, broccoli and enriched breads and cereals. Cereals and vegetables are the largest sources of riboflavin in developing countries.

*** Commercial forms:** The commercial form (CAS: 83-88-5) is a yellow to orange-yellow crystalline powder having a slight odour. Riboflavin 5′-phosphate sodium (CAS: 130-40-5) is a fine orange yellow crystalline power having a slight odour. It is hygroscopic.

*** Toxicity:** There are no known effects from toxicity. The capacity of the human gastrointestinal tract to absorb orally administered riboflavin may be less than 20 mg in a single dose. Excess is readily excreted, which is typical of other water soluble vitamins.

2.3.4 Niacin: Niacin is a generic term used for nicotinic acid and its derivatives that exhibit the biological activity of niacinamide. These function as a component of the coenzymes nicotinamide adenine dinucleotide (NAD) and nicotinamide adenine dinucleotide phosphate (NADP), which are present in all cells. These coenzymes are essential in oxidation–reduction reactions involved in the release of energy from carbohydrates, fats, and proteins. The coenzyme NAD is also used in glycogen synthesis. Niacin was identified as a result of the search for the cause and cure of pellagra.

*** Units and Requirements:** The 1997–1998 Dietary Reference Intakes recommendations are given as niacin equivalents (NEs). One niacin equivalent is equal to 1 mg of niacin. In addition, the Food and Nutrition Board suggests that 60 mg tryptophan is equivalent to 1 NE. Ranges are from 14 to 16 for adult men and women, respectively, or 6.6 NE per 1000 kcal. Pregnancy dietary reference intake is at 18 NE and lactation at 17 NE.

* **Sources:** Niacin is widely distributed in plant and animal foods. Good sources include meats (including liver), dairy products, cereals, legumes and seeds. Green leafy vegetables and fish, especially shellfish, as well as enriched breads and cereals, also contain appreciable amounts.

*** Commercial forms:** Nicotinic acid, 3-pyridinecarboxylic acid (CAS: 59-67-6) is a white or light yellow crystal or crystalline powder. It is odourless or has a slight odour. Niacin amide (CAS: 98-92-0) is also a white, crystalline powder. It is odourless, or nearly so, but does have a bitter taste. Storage should be in a well-closed containers. Niacinamide ascorbate is also available as a nutrient in foods. The combination of ascorbic acid and niacinamide is a lemon yellow coloured powder that is odourless or has a very slight odour.

*** Toxicity:** High doses of niacin may be toxic to the liver. Large doses of nicotinic acid have been shown to reduce serum cholesterol concentrations. However, there are side effects that include flushing of the skin, hyperuricemia, hepatic and ocular abnormalities and occasional hyperglycemia.

2.3.5 Vitamin B6: There are six nutritionally active B6 vitamers occurring in foods. Vitamin B6 is essential in the metabolism of tryptophan and its conversion to niacin. The immune responses of young and elderly humans are affected by the nutritional status of vitamin B6.

*** Deficiencies** of vitamin B6 are relatively rare. However, some medications may interfere with metabolism of vitamin B6. Signs of deficiency in adults include stomatitis, cheilosis, glossitis, irritability, depression and confusion.

*** Units and Requirements:** Changes in recommended intakes are now in place with the 1997–1998 Dietary Reference Intakes; males 14 to 50 at 1.3 mg, males 51 and older at 1.7 mg, females 14 to 18 at 1.2 mg, females 19 to 50 at 1.3 mg and females older than 51 at 1.5 mg. Pregnancy levels are at 1.9 mg and lactation at 2.0 mg. Recommendations are based on metabolic studies of intake of vitamin B6 and protein intakes of selected population groups.

*** Sources:** Best sources of vitamin B6 are yeast, wheat germ, pork, liver, whole grain cereals, legumes, potatoes, bananas and oatmeal. Plant foods contain primarily the pyridoxine form, and animal products contain primarily the pyridoxal and pyridoxamine forms.

*** Commercial forms:** Vitamin B6 is available commercially in the form of pyridoxine hydrochloride (CAS: 58- 56-0) as a colourless or white crystal or a white crystalline powder. It is stable in air and slowly affected by sunlight. It should be stored in light-resistant containers to avoid exposure to sunlight.

*** Toxicity**, although relatively rare, high doses of vitamin B6 have been used in an attempt to treat conditions like premenstrual syndrome and have resulted in a small number of cases of neurotoxicity and photosensitivity.

2.3.6 Pantothenic Acid: Pantothenic acid was first synthesized in 1940. As a primary constituent of coenzyme A, it is involved in many areas of cellular metabolism including the synthesis of cholesterol, steroid hormones, vitamin A, vitamin D, and heme A. It is involved in the release of energy from carbohydrate and in the degradation and metabolism of fatty acids.

* **Deficiencies:** Pantothenic acid is widely available so deficiencies are rare. When there are conditions of severe malnutrition, deficiencies may be detected that mainly affect the adrenal cortex, nervous system, skin, and hair. Insufficiency is characterized by a burning sensation in the soles of feet.

* **Units and Requirements:** The 1997–1998 Dietary Reference Intakes now provides an adequate intake guideline. For males and females 14 and older adequate intakes are set at 5.0 mg. Pregnancy level is 6.0 mg and lactation 7.0 mg.

* **Sources:** Pantothenic acid is widely distributed in nature. Rich dietary sources include meat, fish, poultry, eggs, whole grain products, and legumes. Especially high levels of pantothenate are found in royal jelly of bees and in the ovaries of tuna fish and cod.

* **Commercial forms:** Calcium pantothenate (CAS: 137-08-6), Racemic calcium pantothenate (CAS: 6381-63-1), D-calcium panthothenate (CAS: 6363-38-8) and Dexpanthenol (CAS: 81-13-0) are calcium salts of Pantothenic acids that are available commercially.

* **Toxicity:** No serious toxic effects are known. Ingestion of excessive amounts may cause diarrhea.

2.3.7 Folate is a generic term for a group of compounds chemically and nutritionally similar to folic acid. Essential to cell division and also for the formation of both red and white blood cells and serves as a single carbon carrier in the formation of heme.

*** Deficiency:** Deficiency of folate results in poor growth, megaloblasticanemia, and other blood disorders, elevated blood levels of homocysteine, glossitis, and gastrointestinal tract disturbances.

*** Units and Requirements:** The 1997–1998 Recommended Dietary Intakes allowances for folate for men and women 14 and older has been set at 400 µg dietary folate equivalents (DFE). Pregnancy levels are set at 600 µg DFE and lactation levels set at 500 µg DFE.

*** Sources:** Folates are ubiquitous in nature and are present in nearly all natural foods. Best sources are legumes such as kidney beans; lima beans; lentils; fresh dark green leafy vegetables, especially spinach; asparagus; turnip greens and broccoli.

*** Commercial forms:** Folic acid (CAS: 59-30-3) is a yellow or yellowish orange, odourless crystal or crystalline powder. Folic acid should be stored in well-closed light-resistant containers.

*** Toxicity:** When ingested in their active forms, folic acid is nontoxic in humans. Being water soluble, excesses tend to be excreted in urine rather than stored in tissue.

2.3.8 Vitamin B12: Initially vitamin B12, also known as cobalamin, was identified as the extrinsic factor of food that is effective in the treatment of pernicious anemia. Vitamin B12 is synthesized by bacteria. It is essential for normal function in the metabolism of all cells, especially cells of the gastrointestinal tract, bone marrow, and nervous tissue.

*** Deficiency:** may take many years to occur since the body reabsorbs much vitamin B12. Deficiencies also produce elevated serum homocysteine levels, which promote heart attacks, thrombotic strokes, and peripheral vascular occlusions.

*** Units and Requirements:** Recommended dietary allowances as of 1997–1998 for males and females 14 and over is 2.4 µg. Pregnancy level is 2.6 µg and lactation level is 2.8 µg. Studies suggest that higher recommendations should be made for elderly due to malabsorption concerns due to atrophic gastritis.

*** Sources:** Usual dietary sources are meat and meat products and to a lesser extent milk and milk products. Richest sources are liver and kidney. Plant products have very little vitamin B12.

*** Commercial forms:** Vitamin B12/cyanocobalamin (CAS: 68-19-9) are dark red crystals or amorphous or crystalline powder. Packaging and storage should be in well-closed containers.

*** Toxicity:** No toxic effects are known.

2.3.9 Biotin: First named vitamin H, it was later proved to be the same as a potent growth factor in yeast known as coenzyme R and was renamed biotin. It functions as the coenzyme for reactions involving the addition or removal of carbon dioxide to or from active compounds. The absorption of both dietary biotin and any biotin synthesized by intestinal bacteria is thought to be prevented by dietary avidin, a glycoprotein found in raw egg white.

* **Deficiency:** Deficiencies are relatively rare and can be characterized by muscle aches, skin rashes, mild depression, slight anemia, and increased serum cholesterol.

*** Sources:** Biotin is widely distributed with major food sources including liver, rice, egg yolks, and vegetables. It may also be found in seeds of many cereals and oilseeds, however it is largely unavailable in this form. Avidin reduces the bioavailability of biotin. Biotin will occur in food as free biotin but is usually bound to protein.

*** Units and Requirements:** For males and females, ages 19 and above, 1997–1998 adequate intake guidelines state 30 µg biotin. This level is increased to 35 µg for lactation.

*** Commercial forms:** cis-Hexahydro-2-oxo-1H-thieno[3,4]imidazole-4-valeric acid and d-biotin (CAS: 58-85- 5) is a practically white crystalline powder. It is stable to air and heat. Packaging and storage should be done in air- tight containers.

*** Toxicity:** There are no known toxic effects.

2.3.10 Choline: Choline is found in most animal tissues and is a primary component of the neurotransmitter acetylcholine. It functions with inositol as a basic constituent of lecithin and is a major donor of methyl groups. The deposition of fats in the liver is prevented by choline. Choline facilitates the movement of fats into cells.

*** Deficiency:** Diets low in choline can have major consequences that include hepatic, renal, pancreatic, memory, and growth disorders.

*** Units and Requirements:** The 1997–1998 Dietary Reference Intakes adequate intake guidelines for males age 14 and above is 550 mg of choline. Guidelines for females 14 to 18 is set at 400 mg of choline and for females 19 and above is set at 425 mg of choline. Pregnancy guidelines are 450 mg, and lactation guidelines are 550 mg.

*** Sources:** Most common foods contain choline. Richest sources of choline are liver, kidneys, brains, wheat germ, brewers' yeast and egg yolk. One form of choline, phosphatidylcholine, is often added to processed foods and acts as an emulsifying agent or as an antioxidant.

*** Commercial forms:** Choline bitartrate (CAS: 87-67-2) is a white, hygroscopic, crystalline powder having an acidic taste. It is odorless or may have a faint trimethylaminelikeodor. Packaging and storage should be in tight containers. Choline chloride (CAS: 67-48-1) is colorless or white crystals or crystalline powder, usually having a slight odor of trimethylamine. It should also be packaged and stored in tight containers.

*** Toxicity:** Excess choline and its relative lecithin can cause short-term discomforts such as gastrointestinal distress, sweating, salivation and anorexia. Long-term health hazards include injury to the nervous and cardiovascular systems.

2.3.11 Inositol: Inositol, as part of inositol-containing phospholipids, functions as cellular mediators of signal transduction, metabolic regulation, and growth. Inositol is important as an intracellular second-messenger precursor. As a natural component of human diets, inositol may be important in the treatment of various psychiatric disorders that are responsive to selective serotonin reuptake inhibitors.

* **Units and Requirements:** No U.S. RDA levels have been established.

* **Sources:** Inositol and its derivatives are widely distributed in nature and occur in animals, higher plants, fungi, and bacteria. Animal products include fish, poultry, meats, and dairy products. Inositol is also present in high concentrations in breast milk.

* **Commercial forms:** Inositol (CAS: 87-89-8) occurs as fine, white crystals or as white crystalline powder. It should be packaged and stored in well closed containers.

* **Toxicity:** Excessive dietary inositol appears not to be toxic, except in certain clinical situations where its metabolism is impaired.

Self-Assessment Exercises

1. What is the toxicology of vitamin C?
2. What is the effect of deficiency in Folate?
3. What is inositol vitamin good for?

2.4 Summary

Water soluble vitamins dissolve in water readily to form solutions. All the series of compounds of the vitamin B complex and vitamin C are water soluble. The other vitamins, i.e. vitamins A, D, E and K are insoluble in water but soluble in fats and oils. They are said to be fat soluble. All vitamins are obtained naturally from plant sources but could also be procured commercially. Their deficiency in the body can cause conditions of ill-health. E.g. lack of vitamin B causes beriberi while lack of vitamin C can cause scurvy.

In this unit, we have learnt water soluble vitamins. They include Vitamin C and the Vitamin B complexes of Thiamin, Riboflavin, Niacin, Vitamin B6, Pantothenic acid, Folate, Vitamin B12, Biotin, Cholin and Inositol. Their study was with respect to their deficiencies, units and requirement, source, commercial form and toxicity.

2.5 References/Further Readings

Aukeman, H. M., Holub, B. J. 1994. Inositol and pyrroloquinoline quinone. In: Modern Nutrition in Health and Disease 8th ed., Shils, M. E., Olson, J. A., Shike, M. (Eds.). Williams & Wilkins, Baltimore, pp. 466–472.

Committee on Food Chemicals Codex Food & Nutrition Board. 1996. Food Chemicals Codex, 4th ed. Institute of Medicine, National Academy of Sciences. National Academy Press, Washington, D.C. Niacin

Czeizel, A. E. 1995. Folic acid in the prevention of neural tube defects. J. Pediatr. Gastroenterol. Nutr. 2:4–16.

Driskell, J. A. 1994. Vitamin B6 requirements of humans. Nutr. Res. 14:293–324.

Food & Nutrition Board. 1998. Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin and Choline. Committee on the Scientific Evaluation of Dietary Reference Intakes. National Academy Press, Washington, D.C.

Food and Nutrition Board. 1989. Recommended Dietary Allowances, 10th ed., National Academy Press, Washington, D.C.

Fux, M., Levine, J., Aviv, A., Belmaker, R. H. 1996. Inositol treatment of obsessive-compulsive disorder. Am. J. Psychiatry 153:1219–1221.

Mock, D. M. 1996. Biotin. In: Present Knowledge in Nutrition, 7th ed., Ziegler, E. E., Filer, L. J., Jr. (Eds.). ILSI Press, Washington, D.C., pp. 220–235.

Plesofsky-Vig, N. 1996. Pantothenic Acid. In: Present Knowledge in Nutrition, 7th ed., Ziegler E. E., Filer, L. J., Jr. (Eds.) ILSI Press, Washington, D.C., pp. 237–244.

2.6 Possible Answers to Self-Assessment Exercises

Self-Assessment Exercises

1. Toxicity: Since vitamin C is one of the most commonly used supplements, excessive intake may occur. Symptoms may include diarrhea, abdominal bloating, iron over-absorption, nausea and kidney stones.
2. Deficiency of folate results in poor growth, megaloblasticanemia, and other blood disorders, elevated blood levels of homocysteine, glossitis, and gastrointestinal tract disturbances.
3. Inositol, as part of inositol-containing phospholipids, functions as cellular mediators of signal transduction, metabolic regulation, and growth. Inositol is important as an intracellular second-messenger precursor. As a natural component of human diets, inositol may be important in the treatment of various psychiatric disorders that are responsive to selective serotonin reuptake inhibitors.

UNIT 3 NUTRITIVE ADDITIVES – AMINO ACIDS AND MINERALS

CONTENTS

3.1 Introduction

Amino acids are products of the hydrolysis and digestion of proteins. Amino acids are used mainly by the body for growth and development through the formation of body cells, tissues and organs. There are both essential and non-essential amino acids as well as fatty acids. The non-essential acids are those which are produced by the body while the essential ones are those that cannot be produced by the body but have to be supplied to the body regularly. Minerals and trace minerals are substances of inorganic origin that are needed in our diets for maintaining good health. Dietary supplementation is a procedure for the provision of those essential and necessary food substances which the body needs but cannot produce by itself.

3.2 Learning Outcomes

On completion of this unit, you should be able to:

- discuss amino acids that are approved by the FDA for functional use as nutrients; their use in food processing and their analysis.
- discuss minerals and trace elements in food.
- discuss dietary supplements

3.3 Amino Acids

Amino acids are the structural parts of proteins. Each amino acid unit contains a base NH_2 group and an acid or carboxylic group COOH. Because they contain both a base and an acid, they are capable of both acid and base reactions in the body. There are 22 amino acids divided into two categories, essential and nonessential.

Essential amino acids are those that cannot be adequately synthesized in the body from other amino acids or protein sources and must be provided in diet. The body can synthesize nonessential amino acids. Under certain disease condition or special states of need, there are other amino acids that become essential, known as conditionally essential amino acids. In addition, these are frequently needed only during early development.

Nonessential	**Essential**	**Conditionally Essential**
Alanine	Histidine	Arginine
Arginine	Isoleucine	Cysteine
Asparagine	Leucine	Glutamine
Aspartate	Lysine	Isoleucine
Cysteine	Methionine	Leucine
Glutamate	Phenylalanine	Taurine
Glutamine	Threonine	Tyrosine
Glycine	Tryptophan	Valine
Proline	Valine	
Serine		
Tyrosine		

Table 1: Nonessential, essential and conditionally essential amino acids

Deficiency: Deficiencies of both essential and nonessential amino acids can be seen in elderly people with protein-energy malnutrition. Dietary protein may be decreased and there may be an increase in catabolic reactions. These low levels of amino acids may reflect a severe metabolic disturbance.

Commercial form: Amino acids are non-volatile, crystalline white solids in their pure form. They can decompose at temperatures ranging from 185°C to 342°C. They are all soluble in water to various extents. Almost all amino acids are optically active with corresponding stereoisomers of Dextro (D) configuration, which rotates a plane polarized light to the right or clockwise, and Laevo (L) configuration that turns a plane polarized light to the left or anticlockwise. Glycine is the only amino acid that is not optically active. All are capable of forming salts. They are cheaply obtained and stable. The following are FDA approved amino acids for functional use in foods as nutrients-

DL-Alanine	CAS: 302-72-7
L-Alanine	CAS: 56-41-7
L-Arginine	CAS:74-79-3
L-Arginine monohydrochloride	CAS: 1119-34-2
L-Asparagine anhydrous	CAS: 70-47-3
L-Asparagine monohydrate	CAS: 617-45-8
DL-Aspartic acid	CAS: 5794-13-8
L-Aspartic acid	CAS: 56-84-8
L-Cysteine monohydrochloride	
Monohydrate	CAS:7048-04-6
Anhydrous	CAS: 52-89-1
L-Cystine	CAS: 56-89-3
L-Glutamic acid	CAS: 56-86-0

L-Glutamic acid hydrochloride	CAS: 138-15-8
L-Glutamine	CAS: 56-85-9
Glycine	CAS: 56-40-6
L-Histidine	CAS: 71-00-1
L-Histidine monohydrochloride	
Monohydrate	CAS:5934-29-2
DL-Isoleucine	CAS: 443-79-8
L-Isoleucine	CAS: 73-32-5
DL-Leucine	CAS: 328-39-2
L-Leucine	CAS: 61-90-5
L-Lysine monohydrochloride	CAS: 657-27-2
DL-Methionine	CAS: 59-51-8
L-Methionine	CAS: 63-68-3
DL-Phenylalanine	CAS: 150-30-1
L-Phenylalanine	CAS: 63-91-2
L-Proline	CAS: 147-85-3
DL-Serine	CAS: 302-84-1
L-Serine	CAS: 56-45-1
L-Threonine	CAS: 72-19-5
DL-Tryptophan	CAS: 54-12-6
L-Tryptophan	CAS: 73-22-3
L-Tyrosine	CAS: 60-18-4
L-Valine	CAS: 72-18-4

Table 2: FDA approved amino acids for functional use as food nutrients

Toxicity: Food processing offers several dangers to amino acids. Lysine, for example, when in the presence of reducing sugars, may be lost in a treatment of mild heat. In the presence of severe heating conditions, food proteins become resistant to digestion. Lysine and cysteine when exposed to alkali will react together and form lysinoalanine, which is toxic. Methionine is lost when sulfur dioxide is used for oxidation.

Self-Assessment Exercises 1

1. What are the differences between nonessential, essential and conditionally essential amino acids?
2. List the nonessential, essential and conditionally essential amino acids, known to you

3.4 Minerals and Trace Elements

Minerals are inorganic elements that retain their chemical identity when in a food product. Minerals can be divided into two groups, the major minerals and the trace minerals. Major minerals are those present in amounts larger than 5 g in the human body. The seven major minerals include calcium, phosphorus, potassium, sulfur, sodium, chlorine and magnesium. Sulfur, however, is not traditionally used as a nutritional additive. There are more than a dozen trace elements. Some of the most important trace mineral nutritional additives include iron, zinc, copper, iodine and manganese.

Mineral additives are commercially available in one or several salt forms. Some minerals, including iron, are available in the elemental form. Aside from price considerations, the choice of the source depends on three factors:

- Bioavailability of the mineral in a particular salt form

- Solubility and/or mixability
- Potential effects on final product properties

Minerals cannot be destroyed by heat, air, acid or mixing, and only little care is needed to preserve minerals during food preparation. The ash that remains when a food is burned contains the minerals that were in the food originally.

3.4.1 Calcium is needed to form bones and to keep bones strong. Bones and teeth are the major storage units of calcium of one's body. Bones are continually torn down and built back as the body works to meet its calcium needs. If calcium needs are not met through dietary intake, the body will pull greater amounts of calcium from bones. Without adequate intake of calcium, use of stored calcium will lead to porous bones and eventually to the crippling bone disease called osteoporosis.

*** Sources:** Dairy products are an excellent source of calcium. Other sources include dark green leafy vegetables, broccoli, spinach, sardines, canned salmon and almonds.

*** Units and requirements:** Recommended Dietary Allowances (RDA) for calcium have been increased to 1300 mg for ages 9–18, 1000 mg for ages 19–50, and 1200 mg for age 50 and above.

*** Commercially available forms:** Calcium is commercially available in several forms as a nutrient in foods but, most commonly, as Calcium phosphate monobasic anhydrous (CAS: 7758-23-8) and monohydrate (CAS: 10031-30-8). It occurs as white crystals, granules or granular powder and is sparingly soluble in water but insoluble in alcohol.

3.4.2 Phosphorus: Following calcium, phosphorus is the second major component of bone and teeth. Besides associating with calcium, phosphorus is important as a major regulator of energy metabolism in one's body organs and generates energy in every cell of one's body. Phosphorus also plays an important role in DNA and RNA.

* **Sources:** Most foods contain phosphorus. However, good sources of phosphorus are protein-rich foods including milk, meat, poultry, fish and eggs. Legumes and nuts are good sources as well. Carbonated beverages also contain phosphorus.

*** Deficiency:** With abundant sources of availability of phosphorus, deficiencies are rare. Should deficiency occur, symptoms would include loss of appetite, bone deterioration, weakness and pain

*** Excessive intake** of phosphorus can lead to a decrease in the level of calcium in the body. This may be a potentially serious problem in those that already have low calcium intake. Patients with advanced renal failure often become hyperphosphatemic, as renal failure progresses. Modifying the protein and phosphorus diets of these patients can be a means to slow the progression of renal insufficiency.

*** Recommended Dietary Allowance (RDA)** The current recommendations for males and females of 9 to 18 years of age is 1250 mg and for males and females 19 years of age and above is 700 mg.

*** Commercially Available Form:** Commercially, phosphorus is available in combination with other minerals e.g. calcium phosphate, calcium pyrophosphate, calcium glycerophosphate, ferric phosphate, ferric pyrophosphate, magnesium phosphate, manganese glycerophosphate, potassium glycerophosphate, sodium phosphate, sodium ferric pyrophosphate and sodium pyrophosphate.

3.4.3 Magnesium is an intracellular cation largely found in bones, followed by muscle, soft tissues and body fluids. It is important for role it plays in more than 300 body enzymes. Enzymes regulate body functions including digestion of food, producing energy, making body protein and enabling muscle contractions. Magnesium also plays a part in neuromuscular transmission and activity and works with or against the effects of calcium. Excess magnesium inhibits bone calcification.

*** Dietary Sources of** magnesium include seeds, nuts, legumes and unmilled cereal grains. Green vegetables are also good sources. Diets that are high in refined foods, meat and dairy products are low in magnesium. In the processing of foods like flour, rice and sugar, magnesium is lost and not returned in the enrichment process.

*** Deficiency:** Because magnesium is relatively common, deficiencies are rare. In cases where the body does not obtain magnesium appropriately, deficiency symptoms of irregular heartbeat, nausea, weakness and mental derangement may result. Low magnesium intakes or magnesium deficits in the older population have been linked to various disease conditions, including ischemic heart disease, hypertension, osteoporosis, glucose intolerance, diabetes and stroke.

*** Recommended Dietary Allowance (RDA):** Recommended dietary allowances for males 19 to 30 years old is 400 mg, and from 31 years on is 420 mg. Recommendations for females 19 to 30 years old is 310 mg, and from 31 years on is 320 mg.

*** Commercially Available Forms** of magnesium include:

Magnesium gluconate: anhydrous (CAS: 3632-91-5) and dihydrate (CAS: 59625- 89-7). A white to off-white powder or granulate that is anhydrous, dihydrate or a mixture of both. It is insoluble in ether, sparingly soluble in alcohol, but soluble in water. There are other available salts of magnesium.

❖ **Potassium, Sodium and Chlorine:**

These three minerals are known as electrolytes because of their ability to dissociate into charged ions when dissolved in water. Potassium and sodium form positively charged ions while chlorine forms a negatively ion known as chloride ion. These ions, in delicate balance, help to regulate fluids in and out of body cells.

3.4.4 Potassium is a major cation of intracellular fluid and so it is present in small amounts in extracellular fluid. With sodium, potassium maintains normal water balance, osmotic equilibrium and acid–base balance. Potassium is also important, along with calcium, in the regulation of neuromuscular activity. Potassium promotes cellular growth and helps maintain normal blood pressure. Muscle contractions require potassium.

*** Food sources of potassium:** A wide range of food sources provide potassium including bananas, whole milk, turkey, haddock, okra oranges, and tomatoes.

*** Commercial forms** of potassium include:

Potassium chloride (CAS: 7447-40-7), Potassium gluconate anhydrous (CAS: 299-27-4) and monohydrate (CAS: 35398- 15-3), Potassium glycerophosphate (CAS: 1319-70-6) Potassium iodide (CAS: 7681-11-0), all have their distinguishing characteristics.

3.4.5 Sodium is the major cation of extracellular fluid. As an electrolyte, sodium helps regulate the movement of body fluids in and out of body cells. Sodium also helps muscles relax and helps transmit nerve impulses. Substantial amounts of sodium can be found in bile and pancreatic juices.

*** Most common form of sodium** is sodium chloride or table salt. Processed foods are high in sodium and only a small amount of sodium occurs naturally in foods.

* **Recommended Dietary Allowance (RDA)** is not specified for sodium. For healthy adults, a minimum of 500 mg daily is considered safe and adequate.

* **Indication in hypertension:** In the 1960s sodium restriction began to gain acceptance as a dietary practice to reduce hypertension. Studies have indicated that it is not just the sodium intake but may also be confounding factors ingested with sodium that impact blood pressure. Diets low in potassium or calcium were found to amplify the effect of high sodium chloride intake on blood pressure.

* **Commercial forms** of sodium as a nutrient include:

Sodium ascorbate (CAS: 134-03-2), Sodium chloride (CAS: 7647-14-5) sodium citrate (CAS: 68-04-2) and others, each with its distinct characteristics.

3.4.6 Chlorine: Chloride is the principal anion of extracellular fluids and is widely distributed in the body. Both chloride and sodium amounts and concentrations are responsible for regulation of extracellular fluids. Chloride functions as a regulator of fluids in and out of body cells and as a helper in transmission of nerve impulses. Stomach acid contains chloride which aids in the digestion of foods and absorption of nutrients. Chlorine is found mostly in table salt which is made up of sodium and chloride ions. Small amounts of chloride are found in water supplies.

* **Excessive Chloride**, like excessive sodium, may play a role in high blood pressure. For those individuals who are sensitive, dietary intake should be monitored.

* **Recommended Dietary Allowance (RDA):** There are no Recommended Dietary Allowances for chloride.

* **Commercial Forms:** Chloride is commercially available in combination with other minerals as the following forms: calcium pantothenate, calcium chloride double salt (CAS: 6363-38-8),

choline chloride (CAS: 67-48-1), manganese chloride (CAS: 7773-01-5), potassium chloride (CAS: 7447-40-7) and sodium chloride (CAS: 7647-14-5).

3.4.7 Iron is important as a carrier of oxygen in the haemoglobin of red blood cells. Haemoglobin takes oxygen to body cells, where it is used for energy production. The resulting by-product of energy production, carbon dioxide, is removed by haemoglobin as well. Iron can exist in different ionic states and therefore can serve as a cofactor to enzymes involved in oxidation– reduction reactions. As energy production proceeds, iron gets recycled thus protecting against iron deficiency. Iron is also important for its roles in safeguarding us against infections, converting beta carotene to vitamin A, helping produce collagen and helping make body proteins.

*** Food Source:** Iron is widely available in foods from a variety of sources, both animal and plant. Iron found in plants is only nonheme iron. Iron found in meat, poultry and fish contains both heme and nonheme iron in a ratio of about 40 to 60. Heme iron is more rapidly absorbed in the body then nonheme iron. Absorption of nonheme iron can be increased with consumption of vitamin C food sources.

*** Hindrances-** to nonheme iron absorption can be caused by oxalic acid in spinach and chocolate, phytic acid in wheat bran and legumes, tannins in tea and polyphenols in coffee. These food substances should be limited when trying to absorb iron from plant sources.

*** Recommended Dietary Allowance (RDA)** for males of ages 11 to 18 is 12 mg, and for males 19 and older is 10 mg. For females 11 to 50 years old, the recommended amount is 15 mg. Over 50 the amount drops to 10 mg, largely due to the postmenopausal status of women of this age. Pregnancy raises the recommended amount to 30 mg, and with lactation it is raised to 15 mg.

Iron is needed most during periods of rapid growth and, for women, during childbearing years and pregnancy.

* **Deficiency:** Despite its wide availability, iron deficiency is one of the most common nutritional deficiencies, especially among children and women during childbearing years. Deficiencies can be caused by injury, haemorrhage or illness and can be aggravated by poorly balanced diet containing insufficient iron, protein, folate, vitamin B12, vitamin B6 and vitamin C. Anaemia occurs as a result of iron deficiency and symptoms include fatigue, weakness and general poor health.

* **Iron toxicity:** Excessive iron overload may be caused by hereditary haemochromatosis or transfusion overload. Iron toxicity or poisoning is a short-term disorder that occurs following ingestion of large doses of therapeutic iron. Iron toxicity can lead to severe organ damage and death within hours or days. This is a concern particularly where women in a household are taking iron supplements and children accidently consume large doses of these supplements.

* **Commercial forms** of iron include: Ferric ammonium citrate brown (no CAS), Ferric phosphate (CAS: 10045-86-0), Ferrous lactate (CAS: 5905-52-2), etc.

3.4.8 Zinc: Zinc is second only to iron in its abundance. Zinc assists in the promotion of cell reproduction, tissue growth and tissue repair. It is an essential nutrient for normal wound healing. Zinc supplementation was found to improve cell-mediated immune response in older populations.

* **Food Sources:** Zinc is primarily found in meat, fish, poultry, milk and dairy products. Whole grain products, wheat germ, black-eyed peas and fermented soybean paste (miso) are also good sources of zinc.

*** Recommended Dietary Allowance (RDA)** for males 11 years and older is 15 mg, and for females 11 years and older is 12 mg. Zinc requirements are higher for pregnant and lactating women.

*** Deficiency** in zinc can cause retarded growth, loss of appetite, skin changes and reduced resistance to infections. During pregnancy, zinc deficiencies can cause birth defects.

*** Toxicity:** Zinc toxicity, although rare, can cause deficiency in copper. Toxic levels can also be harmful to the immune system.

*** Commercial Forms** include: Zinc gluconate (CAS: 4468-02-4), Zinc oxide (CAS: 1314-13-2), etc.

3.4.9 Copper is involved as a part of many enzymes that helps the body to produce energy in cells. Copper also helps to make haemoglobin which is needed to carry oxygen in red blood cells. Studies have found that copper is required for infant growth, host defence mechanisms, bone strength, red and white cell maturation, iron transport, cholesterol and glucose metabolism, myocardial contractility and brain development.

*** Food Sources** of copper are highly variable. Rich sources include organ meats, oysters, seafood, nuts, chocolate and seeds.

*** Deficiency** of copper can result from decreased copper stores at birth, inadequate dietary copper intake, poor absorption, elevated requirements induced by rapid growth or increased copper losses. Clinical manifestations of copper deficiency are anaemia, neutropenia and bone abnormalities.

*** Toxicity o**vert toxicity from dietary copper sources is rare.

*** Recommended Dietary Allowance (RDA):** Although there are no established RDA levels for copper, an estimated safe and adequate daily dietary intake (ESADDI) has been established. The ESADDI level for adults is 1.5 to 3 mg/day.

*** Commercial forms** of copper include: Copper gluconate (CAS: 527-09-3), Copper sulphate (CAS: 7758-98-7)

3.4.10 Iodine functions as a part of thyroxin, which is a thyroid hormone. The thyroid regulates the rate at which one's body uses energy. It is involved in the regulation of metabolic activities of cells, especially of the brain during foetal and early postnatal life. When its requirements are not met, functional and developmental abnormalities, such as the growth of goitre, can occur.

*** Food Sources:** Iodine as found in foods is rapidly absorbed as iodide. Iodized salt is the main source of this element. Its main natural source is sea foods such as sea weeds and saltwater fish. Other sources include potatoes, spinach and almonds.

*** Deficiencies** of iodine can occur at all stages of development. During pregnancy, infancy or early childhood, deficiency may lead to endemic cretinism in an infant or child. Cretinism is not reversible. Goitres, the more commonly known iodine deficienc Symptom, can be reversed by providing adequate iodine intake.

*** Toxicity:** Iodine can also be toxic. Goitres, thyroiditis, hypothyroidism and hyperthyroidism may result from excessive iodine in individuals who are salt sensitive.

*** Recommended Dietary Allowance (RDA):** The RDA of iodine for adults is 150 µg/day. During pregnancy, an additional 25 µg/day is recommended due to the demands of the foetus. An additional 50 µg/day is recommended for lactating women.

* **Commercial Forms:** Iodine is available commercially in combination with potassium as potassium iodide. Kelp, a dehydrated seaweed, which is chopped as coarse particles and/or ground to fine powder to provide a salty characteristic taste, is used as a source of iodine.

3.4.11 Manganese functions as a part of several enzymes. Besides magnesium, manganese can also activate numerous enzymes. Manganese is associated with the formation of connective and bony tissues, growth and reproduction as well as carbohydrate and lipid metabolism.

*** Food Sources** of manganese include nuts, seeds, tea and whole grains. Small amounts are found in meat, dairy products as well as sugary and refined foods.

*** Deficiency:** Manganese deficiency symptoms include poor reproductive performance, growth retardation, congenital malformations in offspring, abnormal formation of bones and cartilages as well as impaired glucose tolerance.

*** Recommended Dietary Allowance (RDA):** No RDA exists for manganese. However, the estimated safe and adequate daily dietary intake for adults is 2.0 to 5.0 mg/day.

*** Commercial Forms** of manganese include: Manganese chloride (CAS: 7773-01-5), Manganese gluconate (CAS: 6485-39-8) and others

Self-Assessment Exercises 2

1. (a) What are minerals? (b) State the classes of minerals with examples
2. State the function and source of some major minerals

3.5 Dietary Supplements

In 1994, the United States Congress passed the Dietary Supplement Health and Education Act (DSHEA). Through this legislation, dietary supplements have been defined as ‘‘a product, other than tobacco, intended to supplement the diet that contains at least one or more of the following ingredients: a vitamin, a mineral, an herb or other botanical, an amino acid, or a dietary substance for use to supplement the diet by increasing the total dietary intake; or a concentrate, metabolite, constituent, or extract or combination of any of the previously mentioned ingredients.''

Dietary supplements are regulated as a special category of foods, rather than as a category of drugs. Because these products are meant to supplement the diet by increasing the total dietary intake of a substance, manufacturers do not have to provide information to the FDA to get their product on the market. Once a dietary supplement is marketed, the responsibility for showing that the product is unsafe falls within the jurisdiction of the Food and Drug Administration (FDA). The FDA cannot restrict the product's use unless the product's dangers can be determined. Individual states, however, can take steps within their jurisdictions to restrict or stop the sale of a potentially harmful dietary supplement. Food additives, on the other hand, must go through safety studies and premarket approval processes by the FDA, prior to marketing.

Self-Assessment Exercises 3

1. What is dietary supplement?
2. What is FDA's role in regulating dietary supplements versus the manufacturer's responsibility for marketing them?

3.6 Summary

Both amino acids and minerals are all needed by the body. Amino acids are used mainly by the body for growth and development through the formation of body cells, tissues and organs. There are both essential and non-essential amino acids. The non-essential substances are those which are produced by the body while the essential ones are those that cannot be produced by the body but have to be supplied to the body regularly. Minerals and trace minerals are substances of inorganic origin that are also needed by the body for maintaining good health. Dietary supplementation is a process of providing those essential acids and minerals, which the body needs, but cannot produce by itself.

In this unit you have learnt; The amino acids as body building blocks, Minerals like calcium, phosphorus, magnesium, potassium, sodium and chlorine, Trace minerals such as iron, zinc, copper, iodine and manganese for good health, Dietary supplements as a procedure for providing essential substances which the body needs.

3.7 References/Further Readings

American Dietetic Association. 1999. In the news high-protein/low-carbohydrate diets. http://www.eatright.org/news. Accessed July 5, 1999.

Andrews, M., Gallagher-Allred, C. 1999. The role of zinc in wound healing. Advances in Wound Care 12:137–138.

Camire, M. E., Kantor, M. A. 1999. Dietary supplements: nutritional and legal considerations. Food Tech. 53:87–96.

Crim, M. C., Munro, H. N. 1994. Proteins and Amino Acids. In: Modern Nutrition in Health and Disease, 8th ed., Shils, M. E., Olson, J. A., Shike, M. (Eds.). Williams & Wilkins, Baltimore. Fatty Acids

Engstrom, A., Tobelmann, R. C., Albertson, A. M. 1997. Sodium intake trends and food choices. Am. J. Clin. Nutr. 65:704S–707S.

Food and Nutrition Board. 1998. Recommended Dietary Allowances, 11th ed. National Academy Press, Washington, D.C.

Uauy, R., Olivares, M., Gonzalez, M. 1998. Essentiality of copper in humans. Am. J. Clin. Nutr. 67(Suppl):952S–959S.

Wood, R. J., Zheng, J. J. 1997. High dietary calcium intakes reduce zinc absorption and balance in humans. Am. J. Clin. Nutr. 65:1803–1809.

3.8 Possible Answers to Self-Assessment Exercises

Self-Assessment Exercises 1

1. Essential amino acids are those that cannot be adequately synthesized in the body from other amino acids or protein sources and must be provided in diet. The body can synthesize nonessential amino acids. Under certain disease condition or special states of need, there are other amino acids that become essential, known as conditionally essential amino acids.

2.

Nonessential	**Essential**	**Conditionally Essential**
Alanine	Histidine	Arginine
Arginine	Isoleucine	Cysteine
Asparagine	Leucine	Glutamine
Aspartate	Lysine	Isoleucine
Cysteine	Methionine	Leucine
Glutamate	Phenylalanine	Taurine
Glutamine	Threonine	Tyrosine
Glycine	Tryptophan	Valine
Proline	Valine	
Serine		
Tyrosine		

Self-Assessment Exercises 2

1. Minerals are inorganic elements that retain their chemical identity when in a food product. Minerals can be divided into two groups, the major minerals and the trace

minerals. Major minerals are those present in amounts larger than 5 g in the human body. The seven major minerals include calcium, phosphorus, potassium, sulfur, sodium, chlorine and magnesium. Sulfur, however, is not traditionally used as a nutritional additive. There are more than a dozen trace elements. Some of the most important trace mineral nutritional additives include iron, zinc, copper, iodine and manganese.

2.

Major minerals

Mineral	Function	Sources
Sodium	Needed for proper fluid balance, nerve transmission, and muscle contraction	Table salt, soy sauce; large amounts in processed foods; small amounts in milk, breads, vegetables, and unprocessed meats
Chloride	Needed for proper fluid balance, stomach acid	Table salt, soy sauce; large amounts in processed foods; small amounts in milk, meats, breads, and vegetables
Potassium	Needed for proper fluid balance, nerve transmission, and muscle contraction	Meats, milk, fresh fruits and vegetables, whole grains, legumes
Calcium	Important for healthy bones and teeth; helps muscles relax and contract; important in nerve functioning, blood clotting, blood pressure regulation, immune system health	Milk and milk products; canned fish with bones (salmon, sardines); fortified tofu and fortified soy beverage; greens (broccoli, mustard greens); legumes
Phosphorus	Important for healthy bones and teeth; found in every cell; part of the system that maintains acid-base balance	Meat, fish, poultry, eggs, milk, processed foods (including soda pop)

Magnesium	Found in bones; needed for making protein, muscle contraction, nerve transmission, immune system health	Nuts and seeds; legumes; leafy, green vegetables; seafood; chocolate; artichokes; "hard" drinking water
Sulfur	Found in protein molecules	Occurs in foods as part of protein: meats, poultry, fish, eggs, milk, legumes, nuts

Self-Assessment Exercises 3

1. Dietary supplements have been defined as ‘‘a product, other than tobacco, intended to supplement the diet that contains at least one or more of the following ingredients: a vitamin, a mineral, an herb or other botanical, an amino acid, or a dietary substance for use to supplement the diet by increasing the total dietary intake; or a concentrate, metabolite, constituent, or extract or combination of any of the previously mentioned ingredients.’’
2. Dietary supplements are regulated as a special category of foods, rather than as a category of drugs. Because these products are meant to supplement the diet by increasing the total dietary intake of a substance, manufacturers do not have to provide information to the FDA to get their product on the market. Once a dietary supplement is marketed, the responsibility for showing that the product is unsafe falls within the jurisdiction of the Food and Drug Administration (FDA). The FDA cannot restrict the product’s use unless the product’s dangers can be determined. Individual states, however, can take steps within their jurisdictions to restrict or stop the sale of a potentially harmful dietary

supplement. Food additives, on the other hand, must go through safety studies and premarket approval processes by the FDA, prior to marketing.

UNIT 4 ESSENTIAL FATTY ACIDS AS FOOD ADDITIVES

CONTENTS

4.1 Introduction

Fatty acids are any of several organic acids produced by the hydrolysis of neutral fat and oils (i.e. lipids). Essential fatty acids, like essential amino acids, cannot be produced by the body and so must be provided in diet. Essential fatty acids include linoleic acid (LA) (of omega-6 family) and alpha-linolenic acid (ALA) (of omega-3 family). These two fatty acids are parent compounds for other biologically active long-chain polyunsaturated fatty acids (LCPUFAs).

Linoleic acid can be converted to gamma-linolenic acid (GLA) and arachidonic acid (AA). Alphalinolenic acid can be converted to docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA). These fatty acids are necessary for proper growth, maintenance and functioning of the body. The LCPUFAs are major essential components of membrane phospholipids.

4.2 Learning Outcomes

On completion of this unit, you should be able to:

- discuss essential fatty acids (EFA) with regards to their chemistry, functions as well as their applications to food, food additives and dietary supplements
- evaluate the sources of EFA, foods where they serve as supplements, their regulatory status and toxicology

4.3 Essential Fatty Acids (EFA)

It was first suggested that certain fats are essential for life as early as 1929 (Mead, 1982). That is, although the body could synthesise most fats de novo, certain fatty acids were required as dietary precursors to the more important functional fatty acids. It was later recognized that two specific fatty acids, linoleic acid (LA) and alpha-linolenic acid (ALA), could not be synthesised de novo because of the position of certain double bonds close to the methyl end of the molecule. The twenty carbon fatty acids of the omega-6 and omega-3 families [arachidonic acid (ARA) and eicosapentaenoic acid (EPA), respectively] are the precursors for a family of circulating bioactive molecules called eicosanoids.

*** Deficiency:** Thus, these two fatty acids were considered essential for growth. Without them in the diet, animals developed a series of symptoms such as dry, scaly skin, excessive water consumption, reduced growth, infertility, etc., which are now known as classic symptoms of essential fatty acid (EFA) deficiency. It is now understand that the symptoms associated with the deficiency are not necessarily due to the absence of LA or ALA, but rather to the resulting absence of the products of LA and ALA metabolism—the long-chain polyunsaturated fatty acids (LC-PUFAs).

- **Lack of essential fatty acids:** Similar to classic vitamin deficiencies, essential fatty acid deficiency can be overcome by only a small amount of dietary LA and ALA, and there are not many cases of essential fatty acid deficiency reported in humans. However, once we go beyond the pathologies of EFA deficiency, we recognize that optimum function of our bodies (not absolute function) is very dependent on the amount and ratio of these EFAs and their metabolites. Such a ratio can be, and has been, drastically affected by changes in our diet over the years.
- **Fortification of food:** It is, therefore, quite appropriate to consider the fortification of foodstuffs with certain dietary fats, like food additives, in order to provide an optimal ratio of these EFAs to maximize health and longevity. Such a rationale has been used for the development of new types of food products referred to as ''functional foods.''

4.3.1 Chemistry: The most biologically relevant fatty acids are straight chain hydrocarbons (12–22 carbons in length) with a terminal carboxyl group. They are synthesized by a series of enzymatic steps that result in the successive elongation of precursor molecules by two-carbon increments, and can either be fully saturated or dehydrated by the insertion of one to six double bonds at specific locations in the hydrocarbon chain. All fatty acids with multiple double bonds have the double bonds interrupted by a methylene group, and all double bonds are in the cis configuration. The position of the double bond is indicated by the number of carbon atoms from the functional (acid) group (e.g., oleic acid has a single cis double bond at the Δ9 position). The standard biochemical nomenclature used in this chapter describes the fatty acid in terms of the length of its carbon chain, followed by the number of double bonds, and then the position of those double bonds. Oleic acid is, therefore, referred to as C18:1(Δ9), or a fatty acid with 18 carbons and one double bond at the 9 position, as shown in fig 1.

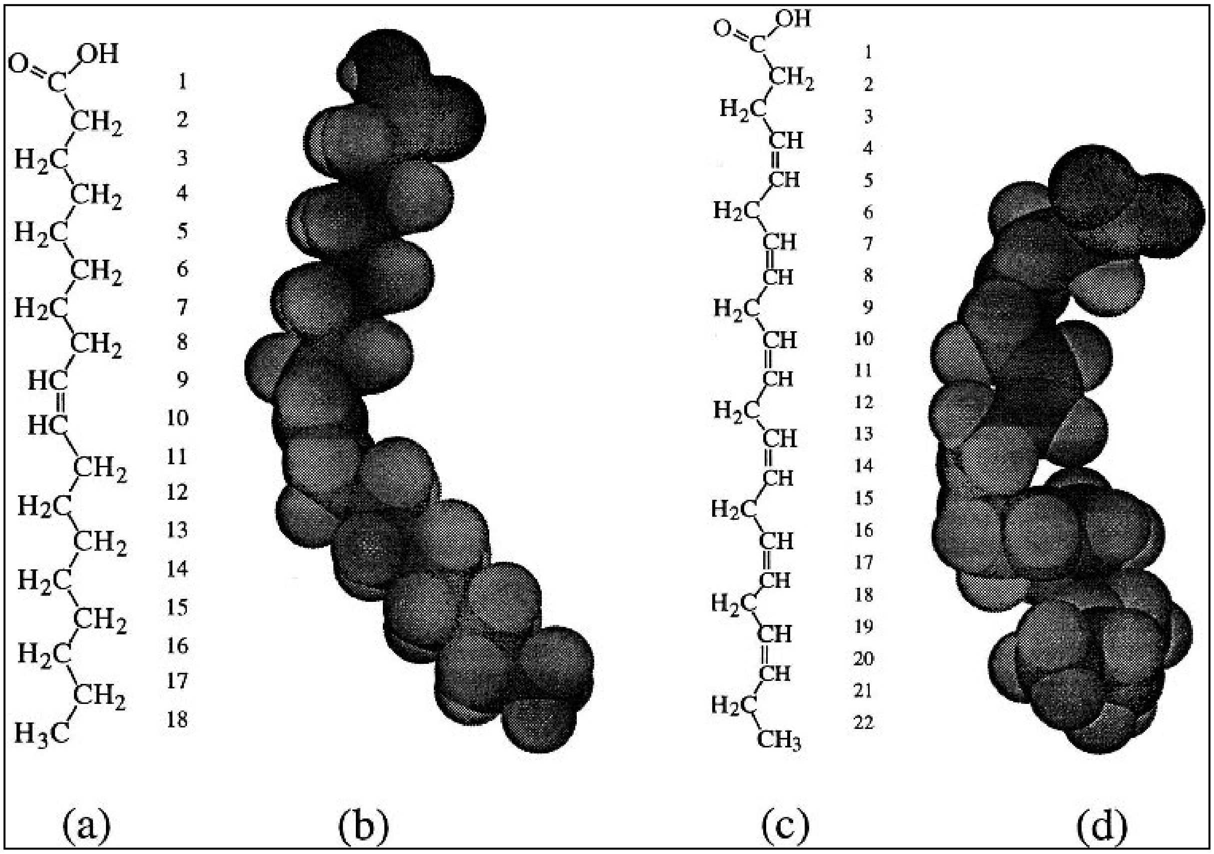


Figure1: Chemical structure of (a) oleic acid in a stick model; (b) in a space filling model; (c) docosahexaenoic acid in a stick model; and (d) in a space filling model.

*** Nutritional form of nomenclature of EFAs:** Nutritionists also use a form of nomenclature which classifies families of fatty acids in terms of the position of the double bond closest to the methyl end of the molecule. Linoleic acid, for example would be chemically described as

C18:2(Δ9,12), but also described as an omega-6 (or n-6) fatty acid since the double bond closest to the methyl end of the molecule is six carbons away from that terminal methyl group.

This nomenclature is functionally useful because different fatty acid families have significantly different physiological and biochemical effects in the body. The other essential fatty acid, linolenic acid, is chemically described as C18:3(Δ9,12,15), and is nutritionally a part of the omega-3 (n-3) family of fatty acids. The scientific and common names for the principle fatty acids in biology are provided in Table 1.

Common name	Scientific name	Chemical notation
Omega-6 family		
linoleic acid (LA)	octadecadienoic acid	C18:2(Δ9,12)
gammalinolenic acid (GLA)	octadecatrienoic acid	C18:3(Δ6,9,12)
dihomogammalinolenic acid	eicosatetraenoic acid	C20:3(Δ8,11,14)
arachidonic acid (ARA)	eicosatetraenoic acid	C20:4(Δ5,8,11,14)
osbond acid	docosapentaenoic acid	C22:5(Δ4,7,10,13,16)
Omega-3 family		
linolenic acid	octadecatrienoic acid	C18:3(Δ9,12,15)
steriodonic acid	octadecatetraenoic acid	C18:4(Δ6,9,12,15)
timnodonic acid	eicosapentaenoic acid (EPA)	C20:5(Δ5,8,11,14,17)
cervonic acid	docosahexaenoic acid (DHA)	C22:6(Δ4,7,10,13,16,19)

Table 1: Common and scientific names of the essential fatty acids and their chemical notations

4.3.2 Functions of Essential Fatty Acids

* Functions as structural entities as membrane protein boundary lipid.

* EFAs play a role as structural entities affecting the performance of membrane-bound proteins

* Twenty carbon metabolites of EFAs have important roles in the body as circulating eicosanoids.

* Many of the eicosanoids have a direct influence on biological responses associated with immune function including:

- -inflammatory response
- -induction of macrophages and
- -production of antibodies in response to some challenges to the organism.

* Generally, the omega-6 eicosanoids have been considered as pro inflammatory and up-regulators of typical immunological responses.

* Required to ensure nominal development of the central nervous system in infants.

* Dietary DHA supplementation has been shown to improve the EFA status and visual function of patients with visual dysfunctional component of DHA.

- **EFAs and cardiovascular function:** The potential role of essential fatty acids (especially omega-3 fatty acids) in cardiovascular function has been well studied for the last 40 years. Since the first observation by Dyerberg and Bang (1979) that indigenous populations in the Arctic who were consuming large amounts of omega-3 fatty acids (from fish and marine mammals) had a very low incidence of cardiovascular disease, there have been hundreds of clinical studies assessing the effects of fish diets or fish oil pills on cardiovascular outcomes.

Most of these studies have concluded that the main effects of fish oil supplementation include the reduction of triglycerides and an improvement of the HDL/LDL ratio.

4.3.3 Applications of EFA addition to food: Food Additives, Foods, or Dietary Supplements:-

Certain LC-PUFAs are unusual in that they are only needed in a small quantity relative to all dietary calories in order to generate the required function. Furthermore, the two classes of EFAs—the omega-3 family and the omega-6 family—may be presented in the diet in different proportions to one another, which means that the omega-3 and the omega-6 are not balanced in the diet. The consequences of this unbalancing has been linked to the increase in incidence of many chronic diseases.

Human diet has changed drastically in the last 100 years. With the advent of modern agricultural processes, the production of seed oils (corn, soybean, palm, etc.) has become so inexpensive that they now make up a major part of our diet. Since the seed oils are also omega-6 dominant, not only has the fat content increased significantly, but the proportion of omega-6 to omega-3 families of EFAs has drastically increased to about 15:1. In other words, a dramatic change in the dietary ratio of omega-6 to omega-3 EFAs, away from the ratio to which our species evolved, has occurred in the last 100 years.

It is for this reason that it is important to return to a much lower ratio of omega-6 to omega-3 EFAs in our diet. This can be done by increasing the levels of omega-3 EFAs or decreasing the level of omega-6 EFAs in our diet. Since the latter requires a radical change in our food consumption habits, we should consider improving the omega-3 content of our diet by supplementing our dietary calories with small amounts of omega-3 LC-PUFAs.

4.3.4 Sources of EFAs:

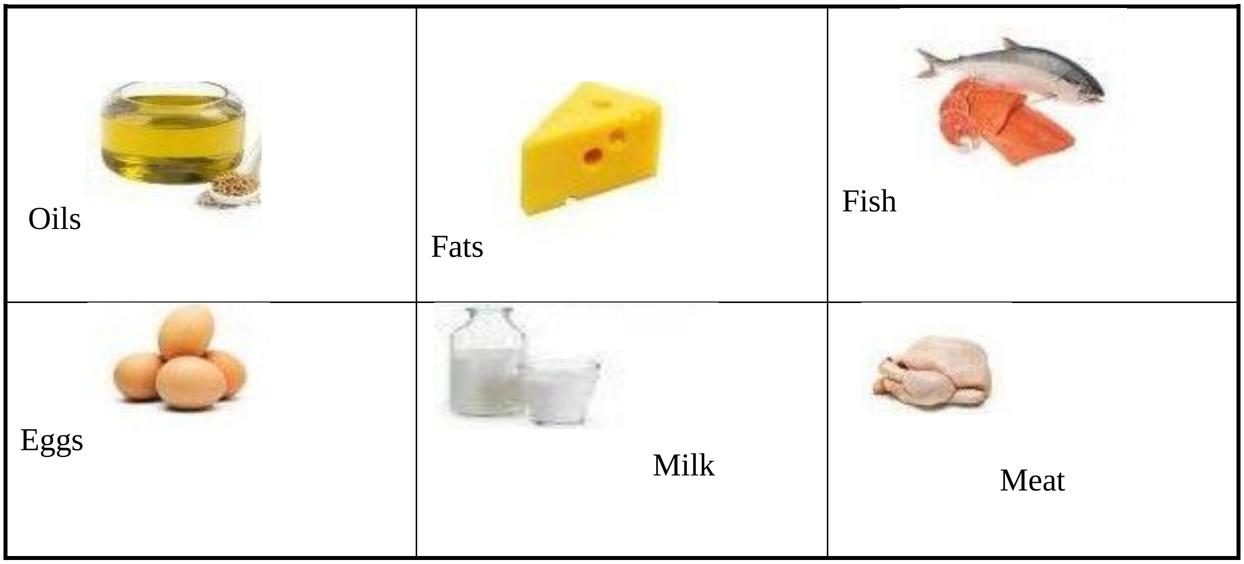


Fig.2 Food sources of EFAs are mainly of marine animal origin, especially fish

Fatty acid	Commercial sources		Levels
Omega-6			
LA	Vegetable oils:	Corn	59
		soy	50
		canola	30
GLA	Specialty plant oils:	primrose	9
		borage	22
		black current seed	17
	Single cell oils:	*Mucor*2	18
		Mortierella	8
ARA	Single cell oils:	*Mortierella*	48
	Animal:	egg yolk	4

Omega-3			
LNA	Vegetable oils:	soy	9
		Canola	7
		flax (linseed)	58
EPA	Animal (fish):	menhaden	10
		salmon	12
		tuna	6
DHA	Animal (fish):	menhaden	13
		salmon4 4	4
		tuna4	17
	Animal:	egg yolk 2a	2
	Single cell oils:	*Crypthecodinium*	47
		Schizochytrium	25

Table 2: Commercial Sources of Essential Fatty Acids

If we choose to fortify food with EFAs, prepare functional foods, or provide dietary supplements to improve the EFA status of the consumer, there are several choices of omega-6 or omega-3 sources that can be used for enrichment. Some of the popular sources of omega-3 and omega-6 fatty acids are shown in Table 2. The choice of the source will be dictated by the sort of benefit the manufacturer wants to convey with that food.

4.3.5 Foods with supplements: Various foods have been supplemented with omega-3 EFAs, particularly in Japan and Southeast Asia. At first, they were indicated as a specialty food, but are now in the mainstream market, including fast and convenience foods. Several companies are marketing specialty drink products in Japan that are enriched in DHA, but at a very low level. Cookies and biscuits have also been produced, but it has proven difficult to disguise the taste of the fish oil, which is the primary source of the EPA and DHA added to many of these foods.

A common problem to all PUFA-enriched products, however, is shelf-life. Since PUFAs are highly susceptible to oxidation, care must be taken in processing, packaging, and storage of the foods. Since foods in the dairy case are generally refrigerated, these make the best candidates for supplementation. Packaging with low oxygen permeability materials with ‘‘flavour seals’’ that are removed by the customer at first use are common to avoid the oxidation and consequential off flavours and odours.

4.3.6 Regulatory status:

*** EFAs as food additives** are generally recognized as safe (GRAS) because of their historical presence in the diet, and are therefore exempt from the premarket approval requirements for food additives. An exception to this generality involves the use of EFAs in infant formulas. Outside the exception of infant formula, the enrichment of a food product with supplemental PUFAs (either omega-6 or omega-3) generally would not require prior approval of the EFA as a food additive.

4.3.7 Toxicology: Essential fatty acids are nutrients that have been in the diet of humans on an evolutionary timescale. They are substituents of the body and are found in fairly high levels in certain tissues. Clearly, the PUFAs themselves are nontoxic under normal dietary circumstances. However, these components are obtained in the diet from a multitude of sources, any of which may carry problematic ‘‘co-travellers,’’ so the requirement of toxicological testing is still critical.

Self-Assessment Exercises 3

1. List the Common and scientific names of the essential fatty acids and their chemical notations
2. Enumerate the Functions of Essential Fatty Acids

4.4 Summary

Essential fatty acids are a type of polyunsaturated fatty acid consisting of two categories: omega-3 and omega-6. These fatty acids are necessary for the body to function properly. They make up compounds called eicosanoids, which are important hormones that control the immune system and other hormones. Because the two omega fatty acids can produce opposite effects, a person should try to balance them in the diet.

In this unit, we have learnt about Essential Fatty Acids (EFA) with reference to their; Chemistry and Functions of EFAs, Applications to Food, Food Additives and Dietary Supplements, Sources, Regulatory status and Toxicology

4.5 Glossary

Additive: A substance added to something in small quantities to improve or preserve it

Amino acids: They are organic compounds composed mainly of nitrogen, carbon, hydrogen, and oxygen.

Cardiovascular: Refers to the heart (cardio) and the blood vessels (vascular).

Chemistry: The science of properties, composition, and structure of substances (defined as elements and compounds), the transformations they undergo, and the energy that is released or absorbed during these processes

Commercial: Covering all the activities and relationships of industry and trade.

Conditionally: In way that depends on something else being done

Deficiencies: The quality or state of being defective or of lacking some necessary quality or element

Essential fatty acids, or EFAs: They are fatty acids that humans and other animals must ingest because the body requires them for good health but cannot synthesize them.

Fatty Acids: They are a class of lipids consisting of carbon, hydrogen, and oxygen, arranged as a linear carbon chain skeleton of variable length, generally with an even number of atoms, with a carboxyl group at one end

Function: The action for which a person or thing is specially fitted or used or for which a thing exists

Hindrance: The state of being interfered with, held back, or slowed down

Mineral: It is a chemical element required as an essential nutrient by organisms to perform functions necessary for life

Nonessential fatty acids: They are the fatty acids the body can synthesize, either through various biochemical reactions or converting the essential amino acids

Nutrition: Is the biochemical and physiological process by which an organism uses food to support its life.

Recommended Dietary Allowances (RDAs): Are the levels of intake of essential nutrients that, on the basis of scientific knowledge, are judged by the Food and Nutrition Board to be adequate to meet the known nutrient needs of practically all healthy persons.

Solubility: Is the maximum amount of a substance that will dissolve in a given amount of solvent at a specified temperature.

Toxicity: Is the degree to which a chemical substance or a particular mixture of substances can damage an organism

Trace Elements: A chemical element present only in minute amounts in a particular sample or environment.

Vitamin: It is an organic molecule that is an essential micronutrient that an organism needs in small quantities for the proper functioning of its metabolism.

4.6 References/Further Readings

Chandra, R. K. 1989. Health Effects of Fish and Fish Oils. ARTS Biomedical, St. John's, Newfoundland, Canada.

Dyerberg, J., Bang, H. O. 1979. Haemostatic function and platelet polyunsaturated fatty acids in Eskimos. Lancet 2:433–446.

FDA. 1993. Food labelling: health claims and label statements: omega-3 fatty acids and coronary heart disease. Federal Register 58:2682–2738.

FAO/WHO 1993. Fats and Oils in Human Nutrition. FAO Food and Nutrition Paper 57. M. Hegsted, Chairman, Publications Division of FAO. Rome, Italy.

Harris, W. S. 1989. Fish oils and plasma lipid and lipoprotein metabolism in humans: a critical review. J. Lipid Res. 30:785–807.

Harris, W. S. 1997. n-3 fatty acids and serum lipoproteins: human studies. Am. J. Clin. Nutr. 65: 1645S–1654S.

Simopoulos, A. P., Kifer, R. R., Martin, R. E. 1986. Health Effects of Polyunsaturated Fatty Acids in Seafoods. Academic Press, Orlando.

Simopoulos, A. P. 1991. Omega-3 fatty acids in health and disease and in growth and development. Am. J. Clin. Nutr. 54:438–463.

Simopoulos, A. P. 1998. Overview of evolutionary aspects of omega-3 fatty acids in the diet. In: The Return of Omega-3 Fatty Acids into the Food Supply: I. Land Based Animal Food Products and Their Health Effects, Simopoulos, A. P. (Ed.). World Review of Nutrition and Diet, Vol. 83. Karger, Basel, pp. 1–11.

4.7 Possible Answers to Self-Assessment Exercises

1.

Common name	**Scientific name**	**Chemical notation**
Omega-6 family		
linoleic acid (LA)	octadecadienoic acid	C18:2(Δ9,12)
gammalinolenic acid (GLA)	octadecatrienoic acid	C18:3(Δ6,9,12)
dihomogammalinolenic acid	eicosatetraenoic acid	C20:3(Δ8,11,14)
arachidonic acid (ARA)	eicosatetraenoic acid	C20:4(Δ5,8,11,14)
osbond acid	docosapentaenoic acid	C22:5(Δ4,7,10,13,16)
Omega-3 family		
linolenic acid	octadecatrienoic acid	C18:3(Δ9,12,15)
steriodonic acid	octadecatetraenoic acid	C18:4(Δ6,9,12,15)
timnodonic acid	eicosapentaenoic acid (EPA)	C20:5(Δ5,8,11,14,17)
cervonic acid	docosahexaenoic acid (DHA)	C22:6(Δ4,7,10,13,16,19)

2. Functions of Essential Fatty Acids

i. Functions as structural entities as membrane protein boundary lipid.

ii. EFAs play a role as structural entities affecting the performance of membrane-bound proteins

iii. Twenty carbon metabolites of EFAs have important roles in the body as circulating eicosanoids.

iv. Many of the eicosanoids have a direct influence on biological responses associated with immune function including:

- -inflammatory response
- -induction of macrophages and
- -production of antibodies in response to some challenges to the organism.

v. Generally, the omega-6 eicosanoids have been considered as pro inflammatory and up-regulators of typical immunological responses.

vi. Required to ensure nominal development of the central nervous system in infants.

vii. Dietary DHA supplementation has been shown to improve the EFA status and visual function of patients with visual dysfunctional component of DHA.

MODULE 3

UNIT 1 FLAVOURING AGENTS

CONTENTS

1.0 Introduction

Flavour is the summation of sensations induced by chemical compounds present in what we eat and drink and in equilibrium at the time of consumption. Flavours can be developed from very diverse processes and source materials, due to standardize high product quality; food production without flavouring is simply inconceivable.

In this unit we shall examine, Flavouring Agents; the process of flavour creation, raw materials, production of flavour, functions and utilization of flavours, flavour safety

1.2 Learning Outcomes

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

- discuss the approaches in the process of flavour creation
- discuss the various functions of quality control and quality assurance
- discuss the functions of flavour
- discuss the application of flavours
- discuss flavour safety

1.3 Flavour

What is a flavour? A consumer, when describing a flavour, has most of his/her senses at work. His/her description of a flavour might be influenced by a psychological response to the sight (colour, shape, appearance, etc.) of the item. Touch and hearing also affect one’s judgement of taste and odour. A trained judge or an expert, on the other hand, tries not to be influenced by stimulation of senses other than taste and odour.

Hall directed his definition to cover the flavour perception: ‘‘Flavour is the sum of those characteristics of any material taken in the mouth, perceived principally by the senses of taste and smell, and also the general pain and tactile receptors in the mouth, as received and interpreted by the brain.''

The Society of Flavour Chemists formulated in 1969 the following definition of the product itself: ''A flavour is a substance which may be a single chemical entity, or a blend of chemicals of natural or synthetic origin, whose primary purpose is to provide all or part of the particular effect to any food or other product taken in the mouth.''

The International Organization of the Flavour Industry (IOFI) defined flavours from the industry's point of view: ''Concentrated preparation, with or without solvents or carriers, used to impart flavour, with the exception of only salty, sweet, or acid tastes. It is not intended to be consumed as such.''

According to the Council of Europe: ''Flavouring is a substance which has predominantly odour-producing properties and which possibly affects the taste.''

1.3.1 The Process of Flavour Creation

Flavour chemists' approach to creation of a flavour varies, depending on the nature of the project and their training. The oldest and simplest method is the artistic approach. The second approach is to combine art with scientific know-how. The third approach is to follow nature's footsteps and develop flavours biosynthetically.

- **The Artistic Approach**

In this approach, the artistic powers of the flavour chemist are at work. The food flavour to be developed—for example, butter—may have its flavour profile described as typical buttery, cooked, cheesy, waxy, creamy, and nutty.

At this stage, the flavour chemist tries to associate the flavour profile of the model food with the raw materials that would serve as the building block in the process of flavour reconstitution. Again, each flavour chemist has a unique interpretation and association. A theoretical simplification of four flavour profiles is shown in Tables 1–4. This is the stage of dreaming and planning that precedes preliminary formulations and bench trials.

Table 1 Flavor Profile of Butter and Its Associated Building Blocks as Perceived by Flavor Chemist

Flavor chemist's perception of butter	Associated components as building blocks
Typical buttery	Diacetyl, starter distillate, acetoin, acetyl propionyl
Lactone, cooked	Δ-Decalactone, Δ-dodecalactone, γ-decalactone
Cheesy	Butyric acid, caprioc acid, caprylic acid, capric acid
Waxy	Myristic acid, palmitic acid, dodecanal
Creamy	*cis*-4-Heptenal, methyl amyl ketone
Nutty	2-Hexenal, pyrazines

Table 2 Flavor Profile of Mango and Its Associated Building Blocks as Perceived by Flavor Chemist

Flavor chemist's perception	Associated components as building blocks
Fresh	Acetaldehyde, hexyl butanoate *cis*-3 hexenol
Sweet	Nerol, γ-octalactone, γ-decalactone, γ-ionone
Cooked/juicy	4-Hydroxy-2,5-dimethyl-3(2H)-furanone
Tropical/sulfury	Dimethyl sulfide
Citrus	Linalool, nerol, citronellol, geraniol
Floral	Linalool, nerol, linalyl acetate

Table 3 Flavor Profile of Chicken (Boiled Type) and its Associated Building Blocks as Perceived by Flavor Chemist

Flavor chemist's perception	Associated components as building blocks
Meaty	4-Methyl-5-thiazole ethanol acetate
Cooked	2,3-Butane dithiol, dimethyl disulfide
Sulfury	Hydrogen sulfide
Fatty/oily	2,4-Decadienal, linolenic acid, oleic acid
Skin	2,4-Heptadienal

Table 4 Flavor Profile of Roast Beef and Its Associated Building Blocks as Perceived by Flavor Chemist

Flavor chemist's perception	Associated components of building blocks
Roasted	Trimethyl pyrazine, 2-ethyl-5-methyl-pyrazine, dimethyl sulfide
Meaty	Dimethyl sulfide, 3,5-dimethyl-1,3,4-trithiolane
Fatty	Oleic acid, hexanoic acid
Cooked	Methyl mercaptan, hydrogen sulfide, dimethyl sulfide

- **The Scientific Approach**

The artistic approach is used along with the scientific knowledge. With the introduction of chromatographic analysis in the early 1960s, new horizons were opened that allowed flavour creations that rivalled nature in their quality. The utilization of chromatography, along with various other analytical techniques, has helped the flavour chemist gain a better understanding of nature's process in producing flavours. This knowledge is used in combination with the artistic skills of the flavour chemist to create unique flavours.

- **The Biosynthetic Approach**

In this approach, the biochemist attempts to duplicate nature's biogenetic pathways. Although science has not yet unlocked many of nature's secrets in developing its flavours, some of the known enzymatic and fermentation reactions are crudely exploited to produce building blocks. Table 6 differentiates between the two broad classifications of natural flavours: primary origin and secondary origin. Under primary origin, flavours of purely biological origin, with little human interference, are listed. Secondary origin flavours, mainly produced through technology, are clearly differentiated. Enzymatically modified cheeses, fermented fruits and wine, and cooked and roasted foods are just a few examples.

Table 5 Classification of Nature's Flavors

Source	Primary origin	Secondary origin: Biological	Secondary origin: Thermal
Botanical	Fruits, vegetables, spices, flowers, nuts	Wine, beer, bread	Coffee, cocoa, caramel
Animal	Fish, beef, chicken, milk	Fermented sausage, cheese	Roast beef, boiled chicken, grilled cheese

Table 6 Examples of Biosynthetic Production of Chemicals

Major product(s) produced in nature	Examples of occurrence	Microorganism applied[a]	Major portion of substrate
Methyl ketones	Cheese	*Penicillium Roqueforti*	Fatty acids
Lactones	Peaches, coconut	*Pityrosporum* species	Lipids
Butyric acid	Butter	*Clostridium Butyricum*	Dextrose
Carveol, carvone, dihydrocarvone, perillyl alcohol	Spearmint and other essential oils	*Pseudomonas* species	Limonene
d-Verbenone d-*cis*-Verbenol		*Aspergillus Niger*	α-Pinene
Cheeselike flavor	Cheese	*Streptococcus* species *Lactobacillus* species	Reconstituted milk
Breadlike flavor	Bread	*Saccharomyces Cerevisiae*	Sugar and milk

[a] Exclusively food microorganisms are applied.

- **Recent Flavour Creation Technology**

Flavour companies are using computer technology to assist the flavourist in their creative task. Many companies have introduced systems where a flavourist has access to a database of thousands of different flavour preparations. By doing selective searches through this database, the flavourist can retrieve a starting formulation which meets specific parameters (e.g., liquid, natural, kosher, and heat stable). From there, the flavourist can tailor a new formulation that meets a specific customer's needs. By the use of this type of technology, the time to develop a new flavour has been reduced significantly.

1.3.2 Raw Materials

Components used to compound flavours are either natural or synthetic. Table 7 illustrates the sources of raw materials available to flavourist chemists. The number of synthetic chemicals permitted for use in food flavours changes on a constant basis due to reviews by authorities.

Table 7 Sources of Raw Materials Used in Flavor Compounding

	Natural	
Synthetic[a]	Botanical	Animal
Benzaldehyde Cinnamic alcohol	Fruit and vegetable juice, extract, and distillate Herbs Spices Nuts	Plasma, drippings Seafood byproducts, enzyme-modified cheese, meat extract

[a] See classifications in Table 8 and examples of the groups in Table 9 .

- **Synthetic Chemicals**

Only selected chemicals are permitted for use in flavour compounding. Chemicals are evaluated for safety, and approved for use when shown to be innocuous. Chemicals identified in natural materials are not allowed simply on the basis of their occurrence in nature. It is important to note that if such a chemical is proven to be harmful, it will not be permitted (examples: coumarin, safrole, thujone). On the other hand, chemicals not yet found in nature might be permitted when they are proved to be safe (examples: ethyl vanillin, dibenzyl ether, glycol acetate). Table 8 and 9 provide examples of some organic components used in flavours.

Table 8 Organic Synthetic Chemicals Used in Flavors

Aromatic		Aliphatic	
Benzenoid	Heterocyclic ring	Cyclic	Acyclic
Phenois	Thiazoles	Lactones	Hydrocarbons
Ethers	Furans		Alcohols
Acetals	Pyrans		Carbonyls
Carbonyls	Thiophenes		Carboxylic acids
Carboxylic acids	Pyrazines		Esters
Esters	Imidazoles		Isoprenoids
Lactones	Pyridines		Sulfur compounds
Sulfur compounds	Pyrroles		Nitrogen compounds
	Oxazoles		
	Thiazoles		

Table 9 a Examples of Groups of Synthetic Chemicals and Their Organoleptic Characteristics

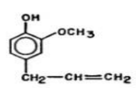
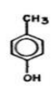
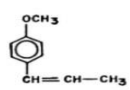
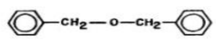
	Example				
Subgroup	Structure	Name	FEMA #	Natural occurrence	Organoleptic characteristics
		Aromatic			
Phenols		Eugenol	2467	Clove oil, banana, cinnamon leaf oil, cocoa, coffee	Clove-like, spicy
		*p*-Cresol	2337	Ylang-ylang, jasmine, raspberry, cheese, coffee, cocoa	Smoky, medicinal
Ethers		Anethole	2086	Anise, fennel, basil, mint, cheese, tea	Anise odor, sweet, herbaceous
		Dibenzyl ether	2371	None reported	Earthy, slightly rosy

Table 9 b Examples of Groups of Synthetic Chemicals and Their Organoleptic Characteristics

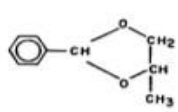
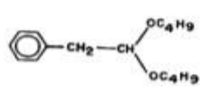
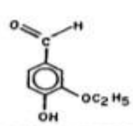
		Aromatic			
Acetals		Benzaldehyde propylene glycol acetal	2130	None reported	Weak, almond-like, dirty
		Phenylacetaldehyde diisobutyl acetal	3384	None reported	Sweet, floral, green
Carbonyls		Ethyl vanillin	2464	None reported	Intense vanilla, sweet, creamy

Table 9 c Examples of Groups of Synthetic Chemicals and Their Organoleptic Characteristics

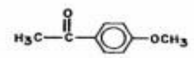
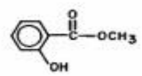
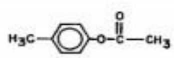
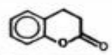
	Example				
Subgroup	Structure	Name	FEMA #	Natural occurrence	Organoleptic characteristics
		Aromatic			
Carbonyls		Acetanisole	2005	Anise seed, tomato, tea	Floral, bitter
Esters		Methyl salicylate	2745	Wintergreen oil, cherry, apple, tomato, wine	Characteristic, wintergreen
		*p*-Tolyl acetate	3073	Cananga oil, ylang-ylang oil	Floral, honey-like
Lactones		Dihydrocoumarin	2381	Sweet clover	Spicy, vanilla

Table 9 d Examples of Groups of Synthetic Chemicals and Their Organoleptic Characteristics

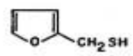
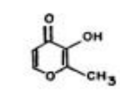
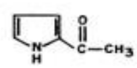
		Aromatic			
Furans and Pyrans		Furfuryl mercaptan	2493	Coffee, beef	Strong, unpleasant, coffee-like
		Maltol	2656	Larch trees, pine needles, chicory, roasted malt, strawberry, bread	Sweet, fruity, jam-like
Pyrroles and pyridines		2-Acetyl pyrrole	3202	Bread, cheese, roasted filberts, tobacco, tea	Strong, roasted
		Pyridine	2966	Wood oil, coffee, tobacco	Penetrating, fishy odor, burnt

Table 9 e Examples of Groups of Synthetic Chemicals and Their Organoleptic Characteristics

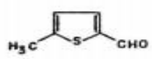
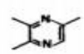
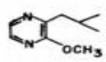
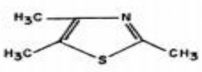
	Example				
Subgroup	Structure	Name	FEMA #	Natural occurrence	Organoleptic characteristics
		Aromatic			
Sulfur compounds (thiophenes)		5-Methyl-2-thiophene-carboxaldehyde	3209	Roasted peanuts	Strong, nutty, meaty
Pyrazines		2,3,5-Trimethylpyra-zine	3244	Baked goods, coffee, cocoa, peanuts, potatoes	Sweet, roasted peanut
		2-Isobutyl-3-methoxy pyrazine	3132	Bell pepper, peas, coffee, potatoes, bread	Powerful, earthy, bell pepper
Thiazoles		2,4,5-Trimethylthiazole	3325	Potatoes, beef, coffee	Chocolate, nutty, coffee

Table 9 f Examples of Groups of Synthetic Chemicals and Their Organoleptic Characteristics

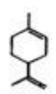
		Aliphatic (cyclic and acyclic)			
Hydrocarbons		*d*-Limonene	2633	Lemon, orange, mandarin, pep-permint	Weak orange or lemon
		α-Pinene	2902	Turpentine, rosemary, lemon, thyme, cheese, nuts	Piney, balsamic
Alcohols		*cis*-3-Hexenol	2563	Apple, orange, raspberry, grape-fruit, tea, straw-berry	Intense, green odor, leafy
		Decanol	2365	Citrus, ambrette mushroom, wine, apple	Fatty, slightly floral odor

Table 9 g Examples of Groups of Synthetic Chemicals and Their Organoleptic Characteristics

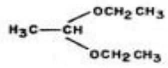
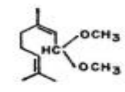
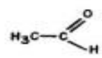
Subgroup	Example: Structure	Example: Name	FEMA #	Natural occurrence	Organoleptic characteristics
		Aliphatic (cyclic and acyclic)			
Acetals		Acetal	2002	Apple, grape, bread, whiskey, rum	Fruity, green
		Citral, dimethyl acetal	2305	None reported	Mild, lemon-like odor, oily, green
Carbonyls (ketones and aldehydes)		Acetaldehyde	2003	Fruits, tobacco, orange, nuts	Pungent and penetrating
		Octanal	2797	Orange, mandarin, grapefruit, rose, beef	Fatty, orange

Table 9 h Examples of Groups of Synthetic Chemicals and Their Organoleptic Characteristics

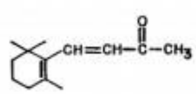
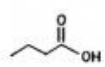
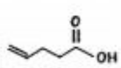
		Aliphatic (cyclic and acyclic)			
Carbonyls (ketones and aldehydes)		β-Ionone	2595	Raspberry, citrus, tomato, wine	Woody, violet
		2-Heptanone	2544	Cheese, banana, clove, apple, bread, meat	Fresh, creamy, spicy
Carboxylic acids		Butyric acid	2221	Dairy products, citronella, bread, strawberry, beef	Rancid, sour milk
		4-Pentenoic acid	2843	None reported	Acrid, caramelic

Table 9 i Examples of Groups of Synthetic Chemicals and Their Organoleptic Characteristics

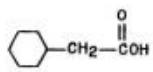
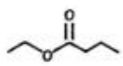
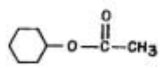
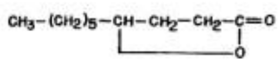
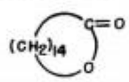
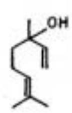
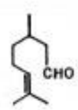
Subgroup	Example: Structure	Example: Name	FEMA #	Natural occurrence	Organoleptic characteristics
		Aliphatic (cyclic and acyclic)			
Carboxylic acids		Cyclohexanacetic acid	2347	None reported	Waxy, fatty
Esters		Ethyl butyrate	2427	Strawberry, olive oil, apple, wine, cheese	Fruity, powerful
		Cyclohexyl acetate	2349	None reported	Fruity, overripe banana, sweet
Lactones		γ-Decalactone	2360	Peach, apricot, strawberry, butter, cheese, meat	Pleasant, fruity, peach-like, creamy

Table 9 j Examples of Groups of Synthetic Chemicals and Their Organoleptic Characteristics

		Aliphatic (cyclic and acyclic)			
Lactones		ω-Pentadecalactone	2840	Angelica root	Musk-like
Functionalized isoprenoids		Linalool	2635	Orange, coriander, nutmeg, peach, tomato, beer	Floral, woody, citrusy
		Citronellal	2307	Citronella, lemon, mandarin, grape, cocoa	Floral, citronella, rose-like

- **Natural Raw Materials**

Since the flavour industry is primarily concerned with the sensory quality of materials. It is very rare that a spice or any other natural food product is used in its native form. The spice or food is processed to separate the chemical compounds from the neutral matrix (cellulose, fiber, pectin, etc.) The goal is to produce the utmost concentration of aromatic chemicals within the minimum amount of neutral components at the most desirable combination of cost, flavour profile, and stability. In practice, one criterion will usually have to be sacrificed to gain the other advantages required.

1.3.3 Production of Flavour

In flavour production, there is no substitute for good manufacturing practices and experienced, conscientious employees for producing finished flavour compounds. The production know-how in this industry is not in the area of sophisticated production equipment but rests, rather, in well-trained staff. The main objective of the production is to ensure the following:

- Good maintenance and handling of the multitude of raw materials used in production
- Strict adherence to formula and process instructions
- Compliance to sanitation and safety rules

For further information, readers are referred to the Code of Practice for the Flavour Industry published by IOFI. Due to the diversity of raw materials and formulations, the flavour industry follows the same strict rules that the pharmaceutical industry adheres to.

1.3.4 Quality Assurance and Quality Control

It is important for the flavour industry to make the distinction and differentiate between the two functions. This task of reproducing the sensory quality of a flavour will be achieved through quality assurance backed up by quality control. Quality assurance uses preventive measures, applied directly to employees and systems, to eliminate problems at their roots. Quality assurance begins with flavour chemists, who must realize that quality starts with their formulations and that whatever process or ingredients are utilized must be exactly reproducible in commercial production. Table 10 describes and differentiates various functions of quality control and quality assurance.

Table 10 Differences Between Quality Control and Quality Assurance

	Quality control	Quality assurance
Goals	Screening system—inspection devised to prevent defective products from reaching the marketplace.	A system devised to complement and support quality control, aimed at preventing problems at their roots, to ideally achieve a ''zero defects'' record.
Fields	Ingredients and products—the inspection, screening and analysis of raw materials and finished goods.	Employees and systems.
End results	Some prevention through the control of ingredients.	Prevention throughout all steps of manufacturing.
	Defects are caught after the fact.	When coupled with an effective quality control program, it is possible to achieve zero defects.
	Defects still exist, and some will pass quality control on to the market.	

Source: Ref. 25.

1.3.5 Functions and Utilization of Flavours

The role of a flavour is simply to impart sensory pleasure to a good, beverage, tobacco, or pharmaceutical, and in doing so it serves a diverse function. It is important to understand the function expected of the flavour so that the type best suited for this function can be delivered.

■ **Flavour Functions**

- **Economic**

Obviously, a simulated flavour or an extender must have economic benefits; otherwise it defeats the purpose of its application. Some healthful, nutritional food preparations might have undesirable tastes (e.g., soya and vitamins). Flavours that can modify their taste and make these nutritional, economical food preparations more palatable would be desirable. Another example of this application is the use of flavour to compensate for flavour losses in food processing or to extend freshness during storage.

- **Physiological**

Various studies on taste and fat digestion provide some indication that taste can alter the metabolic response to a fatty meal. Research on taste and intestinal absorption of glucose proposes that oral stimulation affects intestinal absorption. Monell has recently expanded into the following areas:

1. Chemosensory function and dietary preferences in disease
2. Intravenous feeding and appetite
3. Sodium intake and preference for salty foods
4. Saliva composition and taste perception

- **Psychological**

Although the main role of a flavour is to provide sensory pleasure, psychological analysis of this pleasure can greatly assist in proper flavour selection.

- **Application of Flavours**

Flavours are applied to various products in the food, beverage, tobacco, pharmaceutical, and oral hygiene areas. Lately, some applications have extended to other segments such as the toy industry. Flavoured products fall into two categories:

1. Flavour-dependent: These are foods and beverages that cannot exist without the application of flavours. Examples are hard-boiled candy, chewing gum, carbonated and non-juice drinks, gelatin desserts, and powdered artificial beverages.

2. Flavour-independent: These are products that can be marketed without flavours or for which flavours are legally prohibited. Examples of the first type of product are crackers, cereals, and nuts. The second type includes milk, orange juice, and butter, in which flavour reinforcement is not permitted, unless a new identity is given to the food.

- **Flavour Forms and Dosage**

Flavours are supplied in the following forms:

	Forms	Solvents and carriers
Liquid	Water-, alcohol-, or oil-soluble	Alcohol, propylene glycol, triacetin, benzyl alcohol, glycerin, syrup, water, vegetable oil
Powder	Spray-dried, absorbates, or powder mixes	Gum acacia, starch hydrolysates, selective hydrocolloids, simple carbohydrates
Pastes and emulsions	Emulsion of the oil-in-water type	Same ingredients as for powder and liquid

Flavour strength and potency vary considerably. Some flavours are diluted with solvents and carriers, whereas others are compounds of aromatic chemicals without a solvent. Although the flavour dosage is quite varied, there are some industry acceptable ranges, as shown in Table 11.

Table 11 Flavor Dosage and Most Widely Used Forms Corresponding to Application

	Normal dosage range (% in product as consumed		Flavor form				
			Liquid[a]				
Application	Low	High	W/S	Alc/S	O/S	Powder	Emulsion
Baked goods	0.5	1.5	→		→	→	→
Beverages							
carbonated and still	0.05	0.75	→	→			→
alcoholic	1.0	3.0	→	→			
powdered	0.025	0.40				→	
Cereal	0.25	0.50			→	→	→
Chewing gum	1.0	2.0			→	→	
Condiments	0.1	0.25	→		→	→	→
Confections	0.5	2.00	→	→	→	→	→
Dairy analogues							
cheese and yogurt	0.25	2.00	→		→	→	→
margarine	0.005	0.025	→		→	→	→
Frosting	0.10	0.50	→			→	→
Frozen desserts	0.25	0.75	→				→
Gelatin and puddings	0.05	0.15				→	
Gravies and sauces for main meal	0.25	1.00	→		→	→	
Meat, processed	0.10	0.50	→		→		
Snacks	0.50	0.75			→	→	
Toppings and syrups	0.10	0.25	→				→
Dental preparations (oral hygiene)	1.0	3.0	→	→			
Pharmaceutical							
chewable tablets	1.0	3.0				→	
elixirs	0.10	0.25	→	→			→
liquid preparations	0.25	0.75	→	→			
Animal foods							
feed	0.10	0.40	→			→	
semimoist pet food	0.25	0.75	→			→	→
regular pet food	0.10	0.25	→		→	→	

[a]W/S = water-soluble; Alc/S = alcohol-soluble; O/S = oil soluble.

1.3.6 Flavour Safety

Flavours are part of food, so they must be wholesome and safe. The concern of consumers and the responsibility of flavour manufacturers make safety aspects topics of utmost interest and importance.

Any flavouring substance may be placed, by expert judgement, on a spectrum of confidence regarding safety-in-use, ranging from one extreme to the other. At the extreme of greatest confidence may be placed those substances which fulfil the following description:

- They belong to a group of substances simple in chemical structure and closely related, several of which have been studied toxicologically, and have been found not to possess significant toxicity at levels higher, by a suitable safety factor, than those which could reasonably be encountered in the diet of man.
- They are known, or can, with confidence, be assumed, to be metabolized to safe products or excreted by known mechanisms. By ‘‘metabolized to safe products’’ is implied absence of appreciable tissue accumulation and biotransformation to products that are not considered to constitute any contradiction to the use of the parent compound as a flavouring.

Self-Assessment Exercises

1. What is the use of flavour in food?
2. State the difference between quality control and quality assurance
3. What are the functions of flavours?

1.4 Summary

Most artificial flavors are specific and often complex mixtures of singular naturally occurring flavor compounds combined to either imitate or enhance a natural flavor. These mixtures are formulated by flavorists to give a food product a unique flavor and to maintain flavor consistency between different product batches or after recipe changes. The list of known flavoring agents includes thousands of molecular compounds, and the flavor chemist (flavorists) can often mix these together to produce many of the common flavors.

In this unit you have learnt about Flavouring Agents; the process of flavour creation, raw materials, production of flavour, functions and utilization of flavours, flavour safety

1.5 References/Further Reading

Food Additives Second Edition Revised and Expanded edited by A. Larry Branen, P. Michael Davidson, Seppo Salminen, John H. Thorngate III. Marcel Dekker, Inc. New York, Basel. Retrieved from http://ariefm.lecture.ub.ac.id/files/2012/10/A._Larry_Branen_P._Michael_Davidson_Seppo_SalmiBookFi.org-FOOD-ADDITIVES.pdf

1.6 Possible Answers to Self-Assessment Exercises

1. Flavour can add stability and consistency and can replace costly or bulky ingredients. With minimal or no reaction to other ingredients in the product and a low cost-in-use, manufacturers frequently use flavours to improve the taste of their food and beverage products.

2.

Table 10 Differences Between Quality Control and Quality Assurance

	Quality control	Quality assurance
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	Defects still exist, and some will pass quality control on to the market.	

Source: Ref. 25.

3. The fuctions of Flavour are:

i. Economic

Obviously, a simulated flavour or an extender must have economic benefits; otherwise it defeats the purpose of its application. Some healthful, nutritional food preparations might have undesirable tastes (e.g., soya and vitamins). Flavours that can modify their taste and make these nutritional, economical food preparations more palatable would be desirable. Another example of this application is the use of flavour to compensate for flavour losses in food processing or to extend freshness during storage.

ii. Physiological

Various studies on taste and fat digestion provide some indication that taste can alter the metabolic response to a fatty meal. Research on taste and intestinal absorption of glucose proposes that oral stimulation affects intestinal absorption. Monell has recently expanded into the following areas:

a. Chemosensory function and dietary preferences in disease

b. Intravenous feeding and appetite

c. Sodium intake and preference for salty foods

d. Saliva composition and taste perception

iii. Psychological

Although the main role of a flavour is to provide sensory pleasure, psychological analysis of this pleasure can greatly assist in proper flavour selection.

UNIT 2 FLAVOUR ENHANCERS AND SWEETENERS

CONTENTS

2.1 Introduction

Flavour enhancers are used to bring out the flavour in a wide range of foods without adding a flavour of their own. The concept of flavour enhancement originated in Asia, where cooks added seaweed to soup stocks in order to provide a richer flavour to certain foods. The flavour-enhancing components of seaweed was identified as the amino acid L-glutamate, and monosodium glutamate (MSG) became the first flavour enhancer to be used commercially. The rich flavour associated with L-glutamate was called umami.

In this unit, we shall explore flavour enhancers and sweeteners; food occurrence, stability, nonnutritive sweeteners and nutritive sweeteners

2.2 Learning Outcomes

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

- discuss flavour enhancer and sweetener
- discuss on some of the nonnutritive sweeteners substances
- discuss on some nutritive sweeteners substances

2.3 Flavor Enhancers

- **Definition**

Flavour enhancers can be defined as a group of chemical substances that do not impart any flavor in to the food product but enhance the existing flavor in the food. The most commonly used substances in this category are monosodium L-glutamate (MSG), disodium 5′-inosinate (IMP), and disodium 5′-guanylate (GMP).

- **Food Occurrence**

It is important to note that both compounds comprising umami, that is, glutamate (salts of glutamic acid) and nucleotides, are key components of living organisms. Glutamate is naturally present in virtually all foods, including meat, fish, poultry, milk (human milk), and many vegetables. It occurs in bound form when linked with other amino acids to form protein, and also in free form when it is not protein bound or in peptides. Therefore, protein-rich foods such as human milk, cow’s milk, cheese, and meat contain large amounts of bound glutamate, while most vegetables contain little. Despite their low protein content, many vegetables, including mushrooms, tomatoes, and peas, have high levels of free glutamate.

Glutamate is an important element in the natural and traditional ripening processes that allow the fullness of taste in food to be achieved. Perhaps this is why foods naturally high in glutamate, such as tomatoes, cheese, and mushrooms, have become important to the popular cuisines of the world. Nucleotides are specifically distributed. Disodium 5′- inosinate (IMP) is dominant in meat, poultry, and fish, whereas adenosine monophosphate (AMP) is dominant in crustaceans and mollusks; furthermore, almost all vegetables contain AMP. The GMP content of mushrooms is particularly high, especially in the shiitake species, which is a traditional cooking ingredient in Japan and China.

2.3.1 Stability

- **Glutamate**

Glutamate is not hygroscopic and does not change in appearance or quality during storage. The characteristic taste of glutamate, umami, is a function of its stereochemical molecular structure.

- **5’-Nucleotides**

IMP and GMP are not hygroscopic. IMP and GMP are stable in aqueous solution, but in acidic solution at high temperature, decomposition of the nucleotides occurs.

Enzymatic activity can also have a significant influence on flavor enhancer breakdown and build-up. The phosphomonoester linkage of 5′-nucleotides is easily split by phosphomonoesterases, which are readily found in plant and animal products. From a practical standpoint, these enzymes should be inactivated before the addition of 5′-nucleotide flavor enhancers to foods. Heating or storage below 0°C is usually sufficient to cause inactivation.

- **Toxicity**

An ample supply of a suitable nitrogen source is essential for L-glutamic acid fermentation, since the molecule contains 9.5% nitrogen. Ammonium salts such as ammonium chloride or ammonium sulfate and urea are assimilable. The ammonium ion is detrimental to both cell growth and product formation, and its concentration in the medium must be maintained at a low level.

Self-Assessment Exercises 1

1. What is flavour enhancer?
2. What are examples of Flavour enhancers?

2.4 Sweeteners

Sweetness is one of the most important taste sensations for humans and for many animal species as well. Sweet compounds almost universally induce a positive hedonic response in humans, and this response, which is found in the neonate, is often thought to be inborn. There is scarcely any area of food habits today that does not in some way involve the sweet taste.

Sucrose is one of the most commonly used sweetener. It is not consumed only for its sweetness. It also has many functional properties in foods that make it useful as a bulking agent, texture modifier, mouth-feel modifier, and preservative. Sucrose additionally offers an important energy source for many food fermentations.

The sweetness of individual sweeteners is usually measured in model systems and compared to that of sucrose. The sweetness of individual sweeteners and mixtures can therefore also be estimated and expressed as the concentration of the equisweet reference sugar (usually glucose or sucrose).

The increased sweetness obtained by mixing natural and synthetic sweeteners has been of economic and nutritional interest. The unpleasant aftertastes of many artificial or non-nutritive sweeteners have also stimulated the development of sweetener mixtures to reduce these aftertastes.

- **Sugar Substitutes in Food**

For nutritional and health reasons, there has been a growing desire in most countries to utilize sweeteners including artificial sweeteners other than sucrose.

The use of artificial sweeteners gives rise to a variety of problems in food technology due to some basic differences between them and the carbohydrate sweeteners. Nonnutritive sweeteners are usually not carbohydrate based and therefore have different chemical and physical properties. Often nonnutritive sweeteners also have flavor characteristics that differ from those of carbohydrate sweeteners and are intensely sweet compared to carbohydrate sweeteners. These properties often influence the cost of food manufacturing because the resulting dietetic or special dietary foods are expected to be as acceptable as those with carbohydrate sweeteners.

Table 1 Some Common Nutritive and Nonnutritive Sweeteners

Nutritive sweeteners		Nonnutritive sweeteners
Glucose		*Commonly used*
Fructose		Saccharin
Invert sugar		Cyclamates
Saccharose		Aspartame
Polyols		Acesulfame K
Hydrogenated glucose syrups		*Others*
Lactitol	(E 966)	Thaumatin
Maltitol	(E 965)	Stevioside
Mannitol	(E 421)	Neuhesperidine
Sorbitol	(E 420)	Monellin
Xylitol	(E 967)	Miraculin
		Dulcin
		Sucralose

2.4.1 Nonnutritive Sweeteners

Some properties of Nonnutritive Sweeteners are shown in Table 2 below

Table 2 Some Properties of Nonnutritive Sweeteners

Sweetener	Sweetness in relation to sucrose	Aftertaste	Stability		ADI[a] (mg/kg body weight)
			In solution	During heating	
Acesulfame K	150×	Very slight, bitter	Stable	Stable	0–9
Aspartame	180×	Prolonged sweetness	Not stable in acid conditions	Unstable, sweetness may disappear	40
Cyclamate	30–60×	Chemical flavor	Relatively stable	Relatively stable	0–7
Saccharin	300×	Bitter metallic	Stable in pH < 2.0	Relatively stable	2.5
Stevioside	100–300×	Bitter	Relatively stable	Relatively stable	Not acceptable
Talin	200–2500×	Licorice-like	Relatively stable	Stable at neutral to low pH	Not specified
Sucralose	600×	—	Stable	Stable	0–15

[a] WHO and European Union Scientific Committee on Food.

(a) Saccharin

Chemistry - Saccharin is a general name used for saccharin, sodium saccharin, and calcium saccharin. The molecular formula of saccharin is C7H5NO3S, and the structural formula is presented in Fig. 1. Chemically saccharin is 1,2-benzisothiazol-3(2H)-one-1,1-dioxide and its sodium or calcium salt.

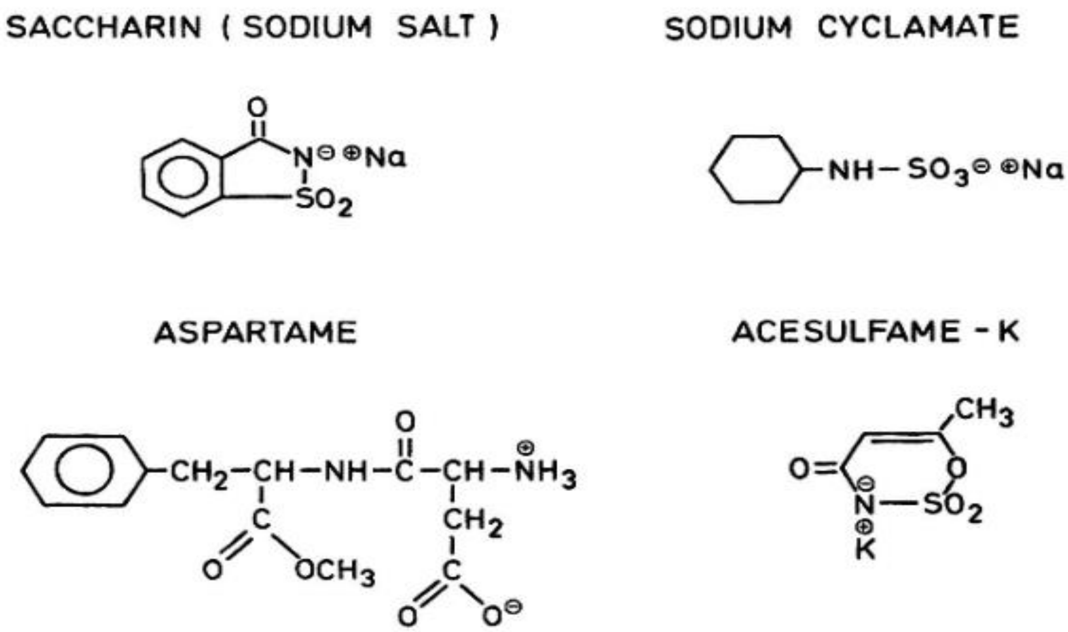

Figure 1 The chemical structures of the most important nonnutritive sweeteners.

Intake - The major uses of saccharin include soft drinks, tabletop sweeteners, and dietetic foods. Saccharin and sodium saccharin have other uses in cosmetics and pharmaceuticals.

Toxicology - The safety of saccharin has been assessed in many epidemiological studies involving both normal subjects and diabetics. Most studies in many population groups including diabetics have failed to demonstrate any statistical evidence of an association between human bladder cancer and saccharin consumption

(b) Cyclamates

Chemistry - Cyclamates is a group name used for the following compounds: cyclamic acid, sodium cyclamate, and calcium cyclamate. The molecular formula for calcium cyclamate is C12H24CaN2O6S2 · 2H2O. Cyclamates are chemically synthesized products that are not found in nature. They are synthesized from cyclohexylamine by sulfonation of various chemicals (chlorosulfonic acid, sulfamic acid) followed by neutralization with hydroxides. Cyclamates are stable at both high and low temperatures. They provide a sweet taste that is 30 times sweeter than sugar. Cyclamates are easily soluble in water and can be used as noncaloric sweeteners in most foods, including soft drinks, confections, desserts, and processed fruits and vegetables.

Toxicology - Epidemiological studies in humans indicate that there is suggestive evidence that the use of cyclamate/saccharin mixtures may be associated with a small increase in the risk of bladder cancer. In addition to carcinogenicity data there are some adverse effects observed in laboratory animals such as testicular atrophy in animals exposed to cyclohexylamine. The clarification of these adverse effects as well as some other questions give rise to the need for further studies.

(c) Aspartame

History - Aspartame was discovered accidentially in the G. D. Searle laboratories by J. M. Schlatter in the early 1960s. Since the discovery safety studies on aspartame have been carefully conducted by Searle laboratories and by many other independent research laboratories. In the early 1980s aspartame was approved in many countries as an alternative sweetener to saccharin and cyclamate.

Chemistry -Chemically, aspartame is the methyl ester of L-aspartyl-L-phenylalanine. Aspartame is produced from the amino acids phenylalanine and aspartic acid. Preliminary amino acids can be produced by fermentation.

Toxicology - Available evidence suggests that normal consumption of aspartame is safe because consumption of aspartame from foods is far below any suspected toxic levels. Data has not provided evidence for serious adverse health effects, although certain individuals might have an unusual sensitivity to the product.

(d) Acesulfame -k

History - Acesulfame -K is one of the most recently introduced nonnutritive sweeteners. It was developed by Hoechst Company in West Germany in 1967 and has only recently been recommended for use in foods in several countries.

Chemistry - Acesulfame K is a name utilized for the potassium salt of 6-methyl-1,2,3-oxathiazine4(3)-one-2,2-dioxide. The composition of acesulfame K is C4H4NO4KS. The compound is freely soluble in water and forms a neutral solution. Acesulfame K is not hygroscopic, and it decomposes during heating at temperatures over 235°C. The molecular weight of the compound is 201.2. At room temperature acesulfame K is an intensely sweet (150–200 times sweeter than sucrose), white, odorless, crystalline powder.

Toxicology - Acesulfame K was first evaluated by JECFA in 1981, but some shortcomings were found in long-term carcinogenicity studies and therefore no acceptable daily intake value was allocated (WHO, 1981).

(e) Thaumatin-

Chemistry - Thaumatin (Thalin) is a macromolecular protein sweetener with a molecular weight of around 22,000. The major protein constituents of the sweetener consist of the normal amino acids except for histidine, which is absent. The extensive disulfide cross-linking confers thermal stability and resistance to denaturation. The tertiary structure of the polypeptide chain gives thaumatin its sweet character. Cleavage of just one disulfide bridge results in a loss of sweet taste.

Toxicology - It has been demonstrated that thaumatin is not allergenic, mutagenic, or teratogenic. Both short-term tests and clinical human exposure studies, some at exaggerated levels, showed no adverse effects. However, long-term studies have not been conducted. It has been questioned whether sufficient data exist for the safety assessment of thaumatin. In any case thaumatin has a long history as a sweetening agent in West Africa and has been used for many years in Japan without any reported reactions.

(f) Sucralose

Sucralose is the generic name of a relatively new intense sweetener made from ordinary sugar. Sucralose was first discovered in 1976, and it is a unique sweetener as it is made from ordinary sugar. It is a thrichloro derivative of the C-4 epimer galactosucrose which is not broken down during its passage through the gastrointestinal tract and thus does not provide calories. Sucralose tastes like sugar, but it is about 600 times sweeter. However, the taste profile is similar to sucrose and it can be used for almost all applications where sucrose is used. The sweetness does not react with food components or other ingredients. It has good water solubility. Sucralose has excellent product stability even under high temperatures and it can be used in a broad range of food products.

Safety - A large number of studies have proven that sucralose is safe for human consumption. Sucralose does not break down in the gastrointestinal tract or accumulate in fatty tissues. Sucralose is also non cariogenic. It is currently evaluated by several regulatory bodies.

(g) Other Nonnutritive Sweeteners

In addition to the traditional and extensively studied nonnutritive sweeteners, a growing number of new compounds have been suggested as sugar substitutes.

2.4.2 Nutritive Sweeteners

(a) Fructose

Fructose is a hexose monosaccharide that is one of the most commonly occurring natural sugars. It is often called fruit sugar or levulose. Free fructose is found in almost all fruits and berries and in most vegetables. Fructose was earlier very difficult to produce and therefore remained unavailable for food use until the late 1960s.

Properties and Uses

Commercially crystalline fructose is produced from sucrose by inversion or from glucose by enzymatic isomerization. One of the major advantages of the use of crystalline fructose is its relative sweetness, which is about 1.5 times that of sucrose. Fructose is the only carbohydrate with a sweetness higher than that of sucrose on a weight basis. Usually smaller amounts of fructose are needed for the same sweetness in food products, and this often results in reduction of energy content. Fructose is also more slowly absorbed than glucose or sucrose, and it does not stimulate insulin per se. Fructose does not increase serum triglycerides in normal subjects. Therefore, fructose has been recommended as a sweetener for diabetics and is presently included in the diabetic diet recommendations in many countries. However, one must take into account the calories in fructose.

(b) Xylitol

Xylitol is a pentitol that can be found in most fruits and berries as well as vegetables. Commercially xylitol is produced from xylan-containing plant material by acid hydrolysis, hydrogenation, and purification.

- Xylitol can also be produced by microbiological methods.

- At room temperature xylitol is equisweet with sucrose and therefore twice as sweet as sorbitol and three times as sweet as mannitol.

- The main application of xylitol appears to be in confectionery, especially in sugar-free products and noncariogenic chewing gum.

- Xylitol can also be utilized in diabetic and dietetic foods provided its energy value is taken into account.

Toxicity

The toxicological studies include studies on carcinogenicity, mutagenicity, and teratogenicity. All these studies have indicated that xylitol is safe for food use. A comprehensive review is available from the World Health Organization (WHO, 1983).

Table 3 Some Properties of Polyol Sweeteners

Polyol	E code	Synonyms	Sweetness (sucrose = 100)	Melting point (°C)	Solubility at 25°C (g/100 g H_2O)	Impact on blood sugar	Laxative effect[a]	ADI[b] (year of evaluation)
Xylitol	E 967	Xylit	90–100	93–94.5	64	Very low	++	Not specified (1985)
Sorbitol	E 420	Glucitol	50–60	93–112	72	Low	++	Not specified (1982)
Mannitol	E 421	Mannit, mannose sugar	50–60	165–168	18	Low	+++	Not specified (1987)
Lactitol	E 966	Lactit	30–40	94–97	149[c]	None	+	Not specified (1983)
Maltitol	E 965	Maltit	80–90	—	Easily soluble	Low	++	Not specified (1985)
Isomaltitol	E 953	Isomalti	50	—		None	+++	Not specified (1985)

[a] Gradual adaptation to large xylitol, sorbitol, mannitol, and lactitol doses occur in most humans during prolonged consumption; initial laxative threshold varies between 20 and 40 g/day.
[b] WHO.
[c] As a monohydrate.

(c) Sorbitol

Sorbitol is a six-carbon sugar alcohol that was originally found in the berries of mountain ash. It occurs in many fruits and vegetables. Sorbitol has the same steric configuration as glucose, and it is chemically synthesized from glucose or dextrose for commercial use.

Toxicology and Safety

The toxicology of sorbitol has been reviewed recently by WHO. The Joint FAO/WHO Expert Group on Food Additives has given sorbitol an ADI of ‘‘not specified,’’ which means that no health hazards are foreseen (WHO, 1982).

(d) Mannitol

Mannitol is a hexitol that is stereoisomeric to sorbitol. It is commonly found naturally in some plant foods, including beets, celery, olives, and seaweed. Mannitol has about 0.4– 0.5 the sweetness of sucrose, and its properties are fairly similar to those of sorbitol.

Toxicology and Safety

A laxative effect is observed in humans after intakes of 20–30 g of mannitol. Toxicity studies have not indicated any adverse effects other than diarrhea. Therefore mannitol is considered safe for use in foods. Mannitol is also on the U.S. FDA GRAS list. An evaluation of its health effects has been conducted. An acceptable daily intake of ‘‘not specified’’ has been allocated for mannitol.

(d) Lactitol

Lactitol is a disaccharide alcohol [(4-O-β-D-galactopyranosyl)-D-glucitol] produced by the hydrogenation of lactose or lactulose. Lactitol as well as most polyols can be applied to special dietary foods that can be consumed by diabetics provided that the calories are taken into account. Lactitol can be used as a sweetener in most foods, but due to its low sweetness it is not very attractive.

Toxicology and Safety

Studies indicate that apart from diarrhea after consumption of large lactitol doses no toxicologically significant adverse effects have been noted (WHO, 1983). The EEC Scientific Committee on Food has accepted lactitol and most other polyols for use in food. However, it was pointed out that laxation may occur at high intakes.

(e) Maltitol

The maltitol molecule, 4-O-β-D-glucopyranosyl-D-glucitol, consists of a glucose and a sorbitol unit linked 1,4 (1,4-glucosyl-glucitol). Maltitol is produced by enzymatic hydrolysis of starch (potato or corn) to obtain a high maltose syrup, which is hydrogenated to the corresponding high maltose syrup, from which crystalline maltitol is obtained.

Toxicity

Maltitol has a low acute toxicity by oral administration (LD_{50} > 24 g/kg body weight). Maltitol is not mutagenic. Teratogenic studies have also been negative.

Self-Assessment Exercises 2

1. What is a sweetener?
2. What are nutritive and nonnutritive sweeteners?
3. State the properties of the nonnutritive sweeteners you know

2.5 Summary

Flavour enhancers amplify and intensify the flavour impact of other flavour compounds in the mouth. The most commonly used flavour enhancers are the sodium salt of glutamic acid, monosodium glutamate (MSG), and the nucleotides disodium-5′-inosinate and disodium-5′-guanylate. Due to their higher flavour potency and synergistic behaviour, nucleotides have increasingly been replacing MSG in foods. Flavour enhancers are present naturally in a wide range of foods, especially meat, fish, mushrooms, and cheese.

Summary for Sweetners?

In this unit, we have learnt the; Definition of flavour enhancers and sweeteners, Food occurrence of food enhancers, Stability of the Glutamate and 5’-Nucleotides, Nonnutritive sweeteners, Nutritive sweeteners

2.6 References/Further Reading

Food Additives Second Edition Revised and Expanded edited by A. Larry Branen, P. Michael Davidson, Seppo Salminen, John H. Thorngate III. Marcel Dekker, Inc. New York, Basel. Retrieved from http://ariefm.lecture.ub.ac.id/files/2012/10/A._Larry_Branen_P._Michael_Davidson_Seppo_SalmiBookFi.org-FOOD-ADDITIVES.pdf

WHO. 1981. Food Additive Series, Vol. 16.

WHO. 1982. Food Additive Series, Vol. 17.

WHO. 1983. Food Additive Series, Vol. 18

2.7 Possible Answers to Self-Assessment Exercises

Self-Assessment Exercises 1

1) Flavour enhancers can be defined as a group of chemical substances that do not impart any flavor in to the food product but enhance the existing flavor in the food.
2) Besides monosodium glutamate, sodium aspartate, disodium inosinate (IMP), disodium guanylate (GMP), disodium cytidylate (CMP), disodium adenylate (AMP), disodium uridylate (UMP), and disodium succinate are considered as flavor enhancers for food applications.

Self-Assessment Exercises 2

1. A sweetener is a substance added to food or drink to impart the flavor of sweetness, either because it contains a type of sugar, or because it contains a sweet-tasting sugar substitute.
2. Nutritive sweeteners provide the body with calories, while nonnutritive sweeteners are very low in calories or contain no calories at all. They can both be added to food and beverages.
3.

Table 2 Some Properties of Nonnutritive Sweeteners

Sweetener	Sweetness in relation to sucrose	Aftertaste	Stability		ADI[a] (mg/kg body weight)
			In solution	During heating	
Acesulfame K	150×	Very slight, bitter	Stable	Stable	0–9
Aspartame	180×	Prolonged sweetness	Not stable in acid conditions	Unstable, sweetness may disappear	40
Cyclamate	30–60×	Chemical flavor	Relatively stable	Relatively stable	0–7
Saccharin	300×	Bitter metallic	Stable in pH < 2.0	Relatively stable	2.5
Stevioside	100–300×	Bitter	Relatively stable	Relatively stable	Not acceptable
Talin	200–2500×	Licorice-like	Relatively stable	Stable at neutral to low pH	Not specified
Sucralose	600×	—	Stable	Stable	0–15

[a] WHO and European Union Scientific Committee on Food.

UNIT 3 FOOD COLORANTS

CONTENTS

3.1 Introduction

Food colouring, or colour additive, is any dye, pigment, or substance that imparts colour when it is added to food or drink. They come in many forms consisting of liquids, powders, gels, and pastes. Food colouring is used in both commercial food production and domestic cooking.

In this unit we shall examine, Food Colorants; synthetic food colorant and natural colour additives

3.2 Learning Outcomes

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

- discuss the common applications of the FD&C Certified Colorants
- discuss extensively on the pigments of plant sources

3.3 Synthetic Food Colorants

In nature, colour is determined by a food's inherent qualities, indicating types of flavour, and degrees of sweetness, ripeness, or decay. However, humans have contrived to add or change the natural colour in foods from very early times and for a variety of reasons—for aesthetic purposes, to increase appetite appeal, for symbolic effect, to make a less desirable food seem more desirable, and to mask defects.

From ancient times, wide varieties of food colorants were derived from natural sources—plant, animal, or mineral. This changed in the middle of the nineteenth century with the discovery of synthetic dyes that soon found their way into food. These synthetics were, in general, less expensive as well as more stable, controllable, and intense in hue than natural colour sources. Since that time, the safety and acceptable use of food colorants, both natural and synthetic, remain controversial topics, eliciting debate, continual scientific study, and periodic legislative action.

- **Food Coloring Regulation**

Government attempts to regulate colouring agents in food have had a long history. There was a 1396 edict in Paris against colouring butter. In 1574 French authorities in Bourges prohibited the use of colour to simulate eggs in pastries, and Amsterdam forbade annatto for colouring butter in 1641. Denmark listed colours permitted for food colouring in 1836, and Germany's Colour Act of 1887 prohibited harmful colours in food. A report to the British Medical Association in Toronto in 1884 resulted in the Adulteration Act, the first list of prohibited food additives. Australia passed the Pure Food Act in 1905.

The United States Food and Drug Act of 1906 restricted synthetic food colours to those that could be tested as safe. Of the eighty colours in use, only seven were approved as certified colours. In 1938 the Food, Drug, and Cosmetics (FD&C) Act approved fifteen dyes for use in food, drugs, and cosmetics and assigned colour numbers instead of their common names (thus, amaranth became Red No. 2).

Government and consumers' concerns regarding food additives intensified in the 1950s with new scientific findings. In 1960 the U.S. Congress passed the Colour Additives Amendment to the FD&C Act, which placed the burden of establishing safety on the food manufacturing industry and created a new category, "colour additives exempt from certification." This includes both "natural colours" and "nature-identical" colours (those synthetically made but chemically identical to natural colours, like beta-carotene and canthaxanthin). The Delaney Clause prohibited any colour additive that could be shown to induce cancer in humans or animals.

Since the 1970s the inclusion of colorants in food has received considerable scrutiny based primarily on concerns regarding the carcinogenic properties of colorants. In 1992 a U.S. court decision interpreted the Delaney Clause to mean that zero levels of carcinogens are permissible. With further research findings, certified colours continue to be delisted.

In response to increased consumer perception that natural colorants are safer, manufacturers have moved toward more natural and less synthetic colorants in food. However, the term "natural," as it pertains to colours, has never been legally defined and has no universally accepted definition. In addition, a small percentage of the population demonstrates sensitivity or allergic reactions to some natural colorants such as cochineal. Currently, consumer groups advocate the minimized use of food colorants, as well as a detailed listing of specific colorants on food labels.

Table 1 Synthetic Color Additives Allowed for Use in Food Worldwide

Common name	FDA nomenclature	CI number	EEC number	Countries permitting[a]
Allura Red AC	FD&C Red No. 40	16035	E129	C, US
Brilliant Blue FCF	FD&C Blue No. 1	42090	E133	C, EEC,[b] J, US
Erythrosine	FD&C Red No. 3	45430	E127	C, EEC, J, US
Fast Green FCF	FD&C Green No. 3	42053	—	US
Indigotine	FD&C Blue No. 2	73015	E132	C, EEC, J, US
Sunset Yellow FCF	FD&C Yellow No. 6	15985	E110	EEC, US
Tartrazine	FD&C Yellow No. 5	19140	E102	C, EEC,[e] J, US
Amaranth	(FD&C Red No. 2)[h]	16185	E123	C, EEC[e]
Brilliant Black BN		28440	E151	EEC[ef]
Brown FK		—	E154	EEC[d]
Carmoisine		14710	E122	EEC[efg]
Chocolate Brown HT		20285	E155	EEC[f]
Green S		44090	E142	EEC[efg]
Patent Blue V		42051	E131	EEC[f]
Ponceau 4R		16255	E124	EEC,[c] J
Quinoline Yellow	D&C Yellow No. 10	47005	E104	EEC[f]
Red 2G		18050	E128	EEC[d]
Yellow 2G		18965	E107	EEC[d]

[a] C—Canada, EEC—European Economic Community, J—Japan, US—United States.
[b] Permitted only in Denmark, Ireland, and the Netherlands.
[c] Permitted only in Ireland, and the Netherlands.
[d] Permitted only in Ireland.
[e] Not permitted in Finland.
[f] Not permitted in Portugal.
[g] Not permitted in Sweden.
[h] Delisted.
Source: Rayner (1991); Jukes (1996); von Elbe and Schwartz (1996).

Table 1 above, shows the Synthetic Colour Additives allowed for use in Food Worldwide.

- **Colorant Applications**

Colorants are added to consumable products for the sole purpose of enhancing the visual appeal.

Possible reasons underlying the need for enhancement include:

i. Correcting for natural variations in food or ingredient colours

ii. Correcting for colour changes during storage, processing, packaging, or distribution

iii. Emphasizing associated flavours or preserving unique identifying characteristics

iv. Protecting flavour and vitamins from photo degradation

Table 2 Common Applications of the FD&C Certified Colorants

Colorant	Common Name	Hue	Applications
FD&C Blue No. 1	Brilliant Blue FCF	Bright greenish-blue	Bakery, beverages, condiments, confections, dairy products, extracts, icings, jellies, powders, syrups
FD&C Blue No. 2	Indigotine	Deep royal blue	Baked goods, cereal, cherries, confections, ice cream, snack foods
FD&C Green No. 3	Fast Green FCF	Sea green	Baked goods, beverages, cherries, confections, dairy products, ice cream, puddings, sherbet
FD&C Red No. 3	Erythrosine	Bluish pink	Baked goods, confections, dairy products, fruit cocktail cherries, snack foods
FD&C Red No. 40	Allura Red AC	Yellowish red	Beverages, cereals, condiments, confections, dairy products, gelatins, puddings
FD&C Yellow No. 5	Tartrazine	Lemon yellow	Bakery, beverages, cereals, confections, custards, ice cream, preserves
FD&C Yellow No. 6	Sunset Yellow FCF	Orange	Bakery, beverages, cereals, confections, dessert powders, ice cream, snack foods

Source: Moore (1991); FDA/IFICF (1993).

Table 2 above shows the common applications of the FD&C Certified Colorants

- **Safety**

The passage of the Pure Food and Drug Act of 1906 formalized the requirements that all synthetic dyes be manufactured under strict control and undergo voluntary certification;

certification of synthetic colorants became mandatory with the passage of the Food, Drug and Cosmetic Act of 1938. Finally, the Color Additive Amendments of 1960 required additional testing using modern techniques, and also invoked the Delaney Clause regarding carcinogenicity. It was clearly recognized from Hesse's time that, even though the primary role of food colorants is cosmetic (their only nutritional contribution being indirect, in the preservation of light-degradable vitamins), colorants nonetheless can have a significant impact on human health.

- **Toxicological Considerations**

Given the ubiquity of colorants in the diet, their inherent safety is, of course, of preeminent concern. In order to safeguard the populace, the concept of an acceptable daily intake (ADI) level was introduced by FDA scientists in the 1950s. ADIs are most commonly established through extensive animal studies; the current Redbook requirements for toxicological testing include [FDA Redbook, cited in IFT (1986)]:

1. One subchronic feeding study, of 90 days duration, in a nonrodent species, usually the dog
2. Acute toxicity studies in rats
3. Chronic feeding studies in at least two animal species (one with in utero exposure), lasting at least 24–30 months
4. One teratology study
5. One multigeneration reproduction study using mice
6. One mutagenicity test

Such testing establishes no adverse effect dietary levels for each specific colorant; these levels are then adjusted by a safety factor (typically 100) to arrive at ADIs. Daily intake levels for the certified colorants and their respective ADIs are presented in Table 13. Once ADIs are obtained they must perforce be compared to the estimated daily intake (EDI); if the EDI is sufficiently below the ADI the additive is deemed safe for consumption. Specific toxicological summaries are presented in the IFT Expert Panel on Food Safety and Nutrition's Scientific Status Summary (IFT, 1986).

Table 3 Comparative Daily Intake Data for the Certified Colorant Dyes

Colorant	Average daily intake (mg/kg)[a]	Adjusted, corrected daily intake (mg/kg)[b]	Acceptable daily intake (mg/kg)[c]
FD&C Blue No. 1	16	0.08	12.5
FD&C Blue No. 2	7.8	0.04	5.0
FD&C Green No. 3	4.3	0.02	12.5[d]
FD&C Red No. 3	24	0.12	0.05[e]
FD&C Red No. 40	100	0.50	Not available
FD&C Yellow No. 5	43	0.22	7.5
FD&C Yellow No. 6	37	0.19	5.0

[a] NAS/NRC data (Newsome, 1990); values for the 99th percentile of the population.
[b] Corrected for estimated over-reporting and adjusted to represent the mean (see text).
[c] FAO/WHO data (Vettorazzi, 1981).
[d] FAO/WHO (1987).
[e] FAO/WHO (1989).

Self-Assessment Exercises 1

1. What are the reasons for the use of colorant?
2. Enumerate the current Redbook requirements for toxicological

3.4 Natural Colour Additives

Most natural colorants are extracts derived from plant tissues. The use of these extracts in the food industry has certain problems associated with it, including the lack of consistent colour intensities, instability upon exposure to light and heat, variability of supply, reactivity with other food components, and addition of secondary flavours and odours. In addition, many are insoluble in water and therefore must be added with an emulsifier in order to achieve an even distribution throughout the food product.

- **Pigments of plant Sources**

The plant kingdom, with its multitude of colours, is most widely studied as a major source of food colorants. Flavonoids, carotenoids, and chlorophyll are the major contributors to the natural colours of most plants, with betalines and curcumin playing a minor yet significant role.

a) Flavonoids

Anthocyanin, chalcone, and flavones belong to a group of compounds collectively known as flavonoids.

Anthocyanin- Anthocyanins are the most established food colorants and may be found in a wide variety of edible plant materials, such as the skin of red apples, plums, and grapes, in addition to strawberries, red cabbage, and shiso (Perilla ocimoidis Varcripsa) leaves and blueberries. Concentrated or spray-dried juices of cranberries, raspberries, and elderberries have also been reported to be used as food colorants in certain food products.

- ***Application*** - Application of anthocyanins in food is restricted due to their ability to participate in a number of reactions, resulting in its decolorization. These include reactions with ascorbic acids, oxygen, hydrogen peroxide, and sulfur dioxide to form colourless compounds; formation of complexes with metal ions and proteins; and hydrolysis of the sugar moieties to form unstable anthocyanidins.

- ***Toxicology*** - In view of the considerable consumption of anthocyanin, toxicological as well as mutagenic studies of the pigment have been carried out. Reviewed of the studies that have been done and concluded that anthocyanin is neither toxic nor mutagenic. On the other hand, anthocyanins were found to have beneficial therapeutic properties and would, therefore, find increasing application in not just the food area but in the medical field as well.

b) Carotenoids

Carotenoids are noted for their great diversity and distribution. They can be found not only in plants (e.g., carrots, tomatoes, and capsicum) but also in bacteria, fungi, algae, and animals. To date over 500 carotenoids have been isolated and identified.

Beta carotene is the most abundant carotenoid in nature, particularly in plant materials. It is the major colouring principle in carrot and as well as palm oil seed extracts. The extracts are oil soluble and impart a yellow colour to foods; they find applications in dairy products, cakes, soup, and confectionery. It is also a known fact that beta carotene is a precursor of vitamin A while possessing antioxidation properties which may help in the prevention of cancer and other diseases. This has resulted in the incorporation of beta carotene in health products, such as functional or nutraceutical beverages, with increasing usage being predicted in the future.

- ***Usage*** - Although present in a lesser amount than beta carotene, annatto, saffron, and gardenia extracts are the more commonly used carotenoids for colouring foodstuffs. Paprika, tomato, carrot, and palm oil seed have also been utilized for the extraction of carotenoids. The carotenoids are used to provide orange and yellow colours in food, particularly in fat based food products.

c) Chlorophyll

Chlorophyll is the green pigment found in all green plants as well as green alga. The pigment is responsible for the photosynthetic process in plants. Chlorophylls a and b are the two main types of chlorophyll pigment found in nature. The former is a bluish green pigment, while the latter is yellowish green in colour. In addition, related pigments known as bacteriochlorophylls are found in photosynthetic bacteria.

Usage - The oil-soluble and water-soluble forms of chlorophyll are commercially available in the form of the stable copper complex. Both forms of commercial chlorophyll are relatively stable toward light and heat. However, unlike the water-soluble chlorophyll, the oil-soluble form is not very stable in acids and alkalis. A major portion of the commercial chlorophyll is used in the food industry for colouring dairy products, edible oil, soups, chewing gum, and sugar confectionery. It is mainly added to fat-based food, particularly canned products, confectionery, and pet foods.

Legislation - The development of food colorant legislation in the rest of the world followed the same pattern as that in the United States. Nevertheless, the list of permitted natural food colorants differs from country to country.

An attempt is therefore being made to create a worldwide permitted list of food colorants. This involves rationalization of food colours legislation by the joint FAO/WHO Codex Alimentarius Commission. Since 1975, the EEC Scientific Committee for Food (SCF) has also undertaken a toxicological review of all permitted colours of member states.

Self-Assessment Exercises 2

1. What are natural food pigments?
2. Which compounds are flavonoids?

3.5 Summary

Colorants differ from each other by various properties such as chemical structures, sources and purpose of use. As it is difficult to classify the colorants according to these properties, they are divided into two groups based on their sources as natural and synthetic

In this unit we examined, Food Colorants; synthetic food colorant and natural colour additives.

3.6 References/Further Reading

Food Additives Second Edition Revised and Expanded edited by A. Larry Branen, P. Michael Davidson, Seppo Salminen, John H. Thorngate III. Marcel Dekker, Inc. New York, Basel. Retrieved from http://ariefm.lecture.ub.ac.id/files/2012/10/A._Larry_Branen_P._Michael_Davidson_Seppo_SalmiBookFi.org-FOOD-ADDITIVES.pdf

https://www.britannica.com/topic/food-additive/Preservatives

3.7 Possible Answers to Self-Assessment Exercises

Self-Assessment Exercises 1

1. Colorants are added to consumable products for the sole purpose of enhancing the visual appeal. Possible reasons underlying the need for enhancement include:
   i. Correcting for natural variations in food or ingredient colours
   ii. Correcting for colour changes during storage, processing, packaging, or distribution
   iii. Emphasizing associated flavours or preserving unique identifying characteristics
   iv. Protecting flavour and vitamins from photo degradation
2. The current Redbook requirements for toxicological testing include [FDA Redbook, cited in IFT (1986)]:

   a. One subchronic feeding study, of 90 days duration, in a nonrodent species, usually the dog
   b. Acute toxicity studies in rats
   c. Chronic feeding studies in at least two animal species (one with in utero exposure), lasting at least 24–30 months
   d. One teratology study
   e. One multigeneration reproduction study using mice
   f. One mutagenicity test

Self-Assessment Exercises 2

1. Foods, particularly fruits and vegetables, are naturally colored mainly by four groups of pigments: the green chlorophylls, the yellow-orange-red carotenoids, the red-blue-purple anthocyanins and the red betanin.
2. Anthocyanin, chalcone, and flavones belong to a group of compounds collectively known as flavonoids.

UNIT 4 FOOD PRESERVATIVES AS ADDITIVES

CONTENTS

4.1 Introduction

Preservatives are a type of food additives added to food to prolong shelf life and keep the products from being broken down by microorganisms. Mold, bacteria, and yeast can cause food spoilage and are found practically everywhere (including the air we breathe).

In this unit you shall explore food preservatives as additives; antioxidants and antimicrobial agents

4.2 Learning Outcomes

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

- discuss food preservative chemical agent and their corresponding mechanism of action
- discuss antioxidants

- discuss the addition of the types of antioxidants to food
- discuss on various antimicrobial agents

4.3 Preservatives

Food preservatives are classified into two main groups: antioxidants and antimicrobials. Antioxidants are compounds that delay or prevent the deterioration of foods by oxidative mechanisms. Antimicrobial agents inhibit the growth of spoilage and pathogenic microorganisms in food.

Table 1

Food preservatives	
chemical agent	**mechanism of action**
Antioxidants	
ascorbic acid	oxygen scavenger
butylated hydroxyanisole (BHA)	free radical scavenger
butylated hydroxytoluene (BHT)	free radical scavenger
citric acid	enzyme inhibitor/metal chelator
sulfites	enzyme inhibitor/oxygen scavenger
tertiary butylhydroquinone (TBHQ)	free radical scavenger
tocopherols	free radical scavenger
Antimicrobials	
acetic acid	disrupts cell membrane function (bacteria, yeasts, some molds)
benzoic acid	disrupts cell membrane function/inhibits enzymes (molds, yeasts, some bacteria)
natamycin	binds sterol groups in fungal cell membrane (molds, yeasts)
nisin	disrupts cell membrane function (gram-positive bacteria, lactic acid-producing bacteria)
nitrates, nitrites	inhibits enzymes/disrupts cell membrane function (bacteria, primarily *Clostridium botulinum*)
propionic acid	disrupts cell membrane function (molds, some bacteria)
sorbic acid	disrupts cell membrane function/inhibits enzymes/inhibits bacterial spore germination (yeasts, molds, some bacteria)
sulfites and sulfur dioxide	inhibits enzymes/forms addition compounds (bacteria, yeasts, molds)

Self-Assessment Exercises 1

1. What are the classes of food preservatives?
2. Enumerate the mechanism of action of the above classes of chemical agents

4.4 Antioxidants

The oxidation of food products involves the addition of an oxygen atom to or the removal of a hydrogen atom from the different chemical molecules found in food. Two principal types of oxidation that contribute to food deterioration are autoxidation of unsaturated fatty acids (i.e., those containing one or more double bonds between the carbon atoms of the hydrocarbon chain) and enzyme-catalyzed oxidation.

The autoxidation of unsaturated fatty acids involves a reaction between the carbon-carbon double bonds and molecular oxygen (O_2). The products of autoxidation, called free radicals, are highly reactive, producing compounds that cause the off-flavours and off-odours characteristic of oxidative rancidity. Antioxidants that react with the free radicals (called free radical scavengers) can slow the rate of autoxidation. These antioxidants include the naturally occurring tocopherols (vitamin E derivatives) and the synthetic compounds butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), and tertiary butylhydroquinone (TBHQ).

Specific enzymes may also carry out the oxidation of many food molecules. The products of these oxidation reactions may lead to quality changes in the food. For example, enzymes called phenolases catalyze the oxidation of certain molecules (e.g., the amino acid tyrosine) when fruits and vegetables, such as apples, bananas, and potatoes, are cut or bruised. The product of these oxidation reactions, collectively known as enzymatic browning, is a dark pigment called melanin. Antioxidants that inhibit enzyme-catalyzed oxidation include agents that bind free oxygen (i.e., reducing agents), such as ascorbic acid (vitamin C), and agents that inactivate the enzymes, such as citric acid and sulfites.

- **Natural Antioxidants**

Tocopherols are the most active chain-breaking antioxidants, and there is an explicit dietary requirement for tocopherols as vitamin E. Tocopherols occur to varying extents in most foods unless they are removed by specific processes during manufacture. Loss of the free radical–scavenging properties of tocopherol is believed to be the basis for its essentiality and the pathologies associated with its deficiency.

- **Natural Antioxidants added to food**

Soluble chain-breaking antioxidants used in foods include ascorbate, as either the naturally occurring free acid or as synthetic ascorbate, and various soluble and insoluble ester forms. The acid form is an excellent electron donor in foods. This is the principle property that makes it an excellent antioxidant at low concentrations.

In response to a perceived desire by consumers for less chemically processed food ingredients, several naturally occurring, chain-breaking antioxidants are being introduced to accomplish essentially the same effects as those of substituted phenols such as butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT).

- **Synthetic Antioxidants in Food**

Many antioxidants have been evaluated for use in foods as preservatives. Whereas natural antioxidants, (e.g., vitamin E) do not withstand processes such as frying and baking, synthetic antioxidants can survive these processes. Four synthetic antioxidants are particularly widespread in their use in foods: BHA, BHT, propyl gallate, and 2-(1,1-dimethylethyl)- 1,4-benzenediol, also known as tertiarybutyl hydroquinone (TBHQ).

- **Synthetic Antioxidants Added directly to Food**

Commercial antioxidants are prepared as solids or blends of liquid. The blends of antioxidants are solubilized and thus are more readily added to foods during processing. Antioxidant mixtures are prepared in solvents such as propylene glycol, which is odourless, tasteless, and inert. . The commercial antioxidants usually are mixtures of phenolic antioxidants and synergists.

- **Synergistic Antioxidants**

Several considerations are basic to the use of phenolic antioxidant formulations in food fats and oil (Sherwin, 1989). Antioxidants are combined to take advantage of their different types of effectiveness. Specific combinations avoid or minimize solubility or colour problems presented by the individual antioxidants; combinations permit better control and accuracy of application; combinations enable more complete distribution or solution of antioxidants and chelating agents in fats and oils; some combinations of antioxidants are more convenient to handle than individual antioxidant compounds; and some provide synergistic effects offered by some antioxidant combinations.

- **Toxicology of Antioxidants**

The toxicological aspects of antioxidants used in the food industry have been reviewed in great detail by Madhavi and Salunkhe (1995).

Self-Assessment Exercises 2

1. What principal types of oxidation contribute to food deterioration?
2. Classify antioxidants based on their occurrence, and discuss the classes briefly.

4.5 Antimicrobial Agents

Processes such as heating, drying, fermentation, and refrigeration have been used to prolong the shelf-life of food products. Some chemical food preservatives, such as salt, nitrites, and sulfites, have been in use for many years, however some have seen extensive use only recently. . While some improvements have been made using packaging and processing systems to preserve foods without chemicals, today antimicrobial food preservatives still play a significant role in protecting the food supply.

In selecting a food antimicrobial agent, several factors must be taken into consideration.

First, the antimicrobial spectrum of the compound to be used must be known. This, along with knowledge of the bioburden of the food product, will allow the use of correct antimicrobial agent for the microorganism(s) of concern. Second, the chemical and physical properties of both the antimicrobial and the food product must be known. Such factors as pK_a and solubility of the antimicrobial and the pH of the food will facilitate the most efficient use of an antimicrobial. Third, the conditions of storage of the product and interactions with other processes must be evaluated to ensure that the antimicrobial will remain functional over time. Fourth, a food must be of the highest microbiological quality initially if an antimicrobial is to be expected to contribute to its shelf-life. Finally, the toxicological safety and regulatory status of the selected compound must be known.

- **Dimethyl Dicarbonate**

The primary target microorganisms for DMDC are yeasts including Saccharomyces, Zygosaccharomyces, Rhodotorula, Candida, Pichia, Torulopsis, Torula, Endomyces, Kloeckera, and Hansenula. DMDC may be used in wine, teas, carbonated and noncarbonated nonjuice beverages (e.g., sports drinks), carbonated and noncarbonated fruit-flavoured or juice beverages.

- **Lysozym**

Lysozyme (1,4-β-N-acetylmuramidase; EC 3.2.1.17) is a 14,600-Da enzyme present in avian eggs, mammalian milk, tears and other secretions, insects, and fish. While tears contain the greatest concentration of lysozyme, dried egg white (3.5%) is the commercial source.

Lysozyme is one of the few naturally occurring antimicrobials approved by regulatory agencies for use in foods. Since egg whites have been used for food since the beginning of recorded history, there is little concern by regulatory agencies about the toxicity of lysozyme. However, there exists the potential for allergenicity to the protein.

- **Natamycin**

Natamycin ($C_{33}H_{47}NO_{13}$; MW, 665.7 Da) is a polyene macrolide antibiotic. Like many polyene antibiotics, natamycin is amphoteric, possessing one basic and one acidic group.

Natamycin is active against nearly all molds and yeasts, but has no effect on bacteria or viruses. Most molds are inhibited at concentrations of natamycin from 0.5 to 6 µg/ mL while some species require 10–25 µg/mL for inhibition.

In addition to cheese, early work with natamycin suggested its use to inhibit fungal growth on fruits and meats. .

- **Nisin**

Nisin by itself has a narrow spectrum affecting only gram positive bacteria, including Alicyclobacillus, Bacillus, Clostridium, Desulfotomaculum, Enterococcus, Lactobacillus, Leuconostoc, Listeria, Pediococcus, Staphylococcus, and Sporolactobacillus.

Nisin is approved in many countries. It is approved to inhibit outgrowth of Clostridium botulinum spores and toxin formation in pasteurized cheese spreads; pasteurized cheese spread with fruits, vegetables, or meats, etc.

Nisin has generally been considered nontoxic.

- **Nitrites**

Nitrite salts (KNO_2 and $NaNO_2$) have been used in meat curing for many centuries. Meat curing utilizes salt, sugar, spices, and ascorbate or erythorbate in addition to nitrite. The reported contributions of nitrite to meat curing include characteristic colour development, flavour production, texture improvement, and antimicrobial effects. Nitrites are white to pale yellow hygroscopic crystals that are quite soluble in water and liquid ammonia but much less so in alcohol and other solvents.

The primary use for sodium nitrite as an antimicrobial is to inhibit the growth and toxin production of Clostridium botulinum in cured meats.

Nitrite is also used in a variety of fish and poultry products. The concentration of nitrite used in these products is specified by the U.S. FDA and USDA regulations. The lethal dose of nitrites in humans is 32 mg/kg body weight. Exposure to nitrites has been implicated as a causative agent of a variety of diseases in human beings and in animals. The major adverse effect is the possible induction of cancer.

- **Organic Acids**

Organic acids are commonly used by food manufacturers as antimicrobial preservatives or acidulants in a variety of food products. This is due to their solubility, flavour, and low toxicity. Many factors influence the effectiveness of organic acids as antimicrobials, including hydrophobicity. However, the most important factor in the use of these compounds is undoubtedly the pH of the food.

In selecting an organic acid for use as an antimicrobial food additive, both the use pH and the pK_a of the acid must be taken into account. The use of organic acids is generally limited to foods with pH 5.5., since most have a $pK_{\mathbf{a}}$ in the range of 3–5.

- **Acetic Acid and Acetate Salts**

Acetic acid (CH3COOH; pK_a 4.75; MW, 60.05 Da), the major component of vinegar, and its salts are widely used in foods as acidulants and antimicrobials. Acetic acid is more effective against yeasts and bacteria than against molds. Only acetic, lactic, and butyric acid–producing bacteria are markedly tolerant to the acid

- **Benzoic Acid and Benzoates**

Benzoic acid is found naturally in apples, cinnamon, cloves, cranberries, plums, prunes, strawberries, and other berries. Sodium benzoate (144.1 Da) is a stable, odorless, white granular or crystalline powder that is soluble in water (66.0 g/100 mL at 20°C) and ethanol (0.81 g/100 mL at 15°C). Benzoic acid (122.1 Da), also called phenylformic acid, occurs as colorless needles or leaflets and is much less soluble in water (0.27% at 18°C) than sodium benzoate. For the latter reason the salt is preferred for use in most foods.

The primary uses of benzoic acid and sodium benzoate are as antimycotic agents. The undissociated from of benzoic acid (pK_a 4.19) is the most effective antimicrobial agent.

Sodium benzoate is used as an antimicrobial in carbonated and still beverages (0.03– 0.05%), syrups (0.1%), cider (0.05–0.1%), margarine (0.1%), olives (0.1%), pickles (0.1%), relishes (0.1%), soy sauce (0.1%), jams (0.1%), jellies (0.1%), preserves (0.1%), pie and pastry fillings (0.1%), fruit salads (0.1%), and salad dressings (0.1%), and in the storage of vegetables (Chipley, 1993).

Toxicology

Benzoates are GRAS preservatives (21 CFR 184.1021; 21 CFR 184.1733; 9 CFR 318.7) up to a maximum of 0.1%. In most countries of the world, the maximum permissible use concentration is 0.15–0.25%.

Evidence has shown that benzoates have a low order of toxicity for animals and humans (FAO/WHO, 1962).

- **Lactic Acid and Lactates**

Lactic acid (pK_a 3.79) is a primary end-product of the lactic acid bacteria and serves to assist in preservation of many fermented dairy, vegetable, and meat products. It is used as a food additive primarily for pH control and flavoring. The antimicrobial activity of the compound is variable.

Sodium lactate (1.8–5.0%) inhibits Clostridium botulinum, Clostridium sporogenes, and Listeria monocytogenes in various meat products. The antimicrobial effect of sodium lactate against L. monocytogenes, Salmonella spp., Yersinia enterocolitica increases with decreasing pH values (5.7–7.0). The U.S. FDA has approved lactic acid as GRAS for miscellaneous and general purpose usage (21 CFR 184.1061) with no limitation upon the concentration used. It may not be used in infant foods and formulas.

- **Propionic Acid and Propionates**

The use of propionic acid and propionates has been directed primarily against molds. Some yeasts and bacteria, particularly gram negative strains, may also be inhibited. The activity of propionates depends upon the pH of the substance to be preserved.

Propionic acid and propionates are used as antimicrobials in baked goods and cheeses.

Propionic acid and calcium and sodium propionates are approved as GRAS (21 CFR 184.1081; 21 CFR 184.1221; and 21 CFR 184.1784). No upper limits are imposed except for products which come under standards of identity.

- **Sorbic Acid and Sorbates**

Sorbic acid and its potassium, calcium, or sodium salts are collectively known as sorbates. As with other organic acids, the antimicrobial activity of sorbic acid is greatest in the undissociated state. The effectiveness of the compound is greatest as the pH decreases below 6.5. Food-related yeasts inhibited by sorbates include species of Brettanomyces, Byssochlamys, Candida, etc.

Sorbates have been found to inhibit the growth of yeasts and molds in cucumber fermentations, high-moisture dried prunes and cheeses.

- **Other Organic Acids**

While citric acid generally is not used as an antimicrobial, it has been shown to possess activity against some molds and bacteria. Fumaric acid has been used to prevent the occurrence of malolactic fermentation in wines and as an antimicrobial agent in wines.

Many other organic acids, including adipic, caprylic, malic, succinic, and tartaric have been evaluated for their antimicrobial properties and has been found useful as food additives.

- **Parabens**

Alkyl (methyl, ethyl, propyl, butyl, and heptyl) esters of p-hydroxybenzoic acid are collectively known as the ‘‘parabens.’ Esterification of the carboxyl group of benzoic acid allows the molecule to remain undissociated up to pH 8.5 versus benzoic acid with a pK_a of 4.2.

Parabens are generally more active against molds and yeast than against bacteria. Against bacteria, they are more effective against gram positive than gram negative bacteria.

Parabens are known to have low toxicity. They are rapidly hydrolyzed, conjugated in the body, and excreted in the urine. Parabens in foods have been reported to cause dermatitis of unknown etiology.

- **Phosphates**

Phosphates are used extensively in food processing. Some phosphate compounds, including sodium acid pyrophosphate (SAPP), tetrasodium pyrophosphate (TSPP), sodium tripolyphosphate (STPP), sodium tetrapolyphosphate, sodium hexametaphosphate (SHMP), and trisodium phosphate (TSP), have demonstrated variable levels of antimicrobial activity in foods.

There are over 30 phosphate salts used in food products and their functions include buffering or pH stabilization, acidification, alkalization, sequestration or precipitation of metals, formation of complexes with organic polyelectrolytes (e.g., proteins, pectin, and starch), deflocculation, dispersion, peptization, emulsification, nutrient supplementation, anticaking, antimicrobial preservation, and leavening (Ellinger, 1981).

Excessive intake of phosphates may decrease the availability of calcium, iron, and other minerals; however, no adverse effects have been reported with moderate doses.

Problems in humans are likely to occur when high levels of phosphates are consumed, as in large quantities of soft drinks.

- **Sulfites**

Sulfur dioxide and its various salts claim a long history of use dating back to times of the ancient Greeks. They have been used extensively as antimicrobials and to prevent enzymatic and nonenzymatic discoloration in a variety of foods. The salts of sulfur dioxide include (formula; solubility in g/L at temperature specified): potassium sulfite (K2SO3; 250, 20°C), sodium sulfite (Na2SO3; 280, 40°C), potassium bisulfite (KHSO3; 1000, 20°C), sodium bisulfite (NaHSO3; 3000, 20°C), potassium metabisulfite (K2S2O5; 250, 0°C), and sodium metabisulfite (NaS2O5; 540, 20°C) (Ough, 1993b).

As antimicrobials, sulfites are used primarily in fruit and vegetable products to control three groups of microorganisms: spoilage and fermentative yeasts and molds on fruits and fruit products (e.g., wine), acetic acid bacteria, and malolactic bacteria

Sulfur dioxide is used to control the growth of undesirable microorganisms in soft fruits, fruit juices, wines, sausages, fresh shrimp, and acid pickles, and during extraction of starches. It is added to expressed grape juices used for making wines to inhibit molds, bacteria, and undesirable yeasts. The concentration of sulfur dioxide used depends on the cleanliness, maturity, and general condition of the grapes, but 50–100 ppm (μg/mL) is generally used. At appropriate concentrations, sulfur dioxide does not interfere with wine yeasts or with the flavor of wine. During fermentation, sulfur dioxide also serves as an antioxidant, clarifier, and dissolving agent. The optimum level of sulfur dioxide (50–75 ppm) is maintained to prevent post fermentation changes by microorganisms.

Sulfur dioxide is not only used as an antimicrobial, but also has other functions such as protection against oxidative, enzymatic, and nonenzymatic browning reactions and inhibition of chemically induced color losses. Sulfur dioxide used as a solution in water is very effective and controls the growth of Botrytis, Cladosporium, and other molds on soft fruits. It is used extensively in preserving strawberries, raspberries, and gooseberries after picking for jam production. In this way, jam production may be spread over the year rather than concentrated in the harvesting season. Sulfur dioxide solution in water is used to sanitize equipment.

The U.S. FDA considers sulfur dioxide and several sulfite salts as GRAS (21 CFR).

Self-Assessment Exercises 3

1. Enumerate the factors considered in the selection of food antimicrobial agent
2. List the food antimicrobial agents you know

4.6 Summary

Food preservatives are classified into two main groups: antioxidants and antimicrobials. Antioxidants are compounds that delay or prevent the deterioration of foods by oxidative mechanisms. Antimicrobial agents inhibit the growth of spoilage and pathogenic microorganisms in food.

In this unit we examined food preservatives as additives; antioxidants types and their food additions, we also considered various antimicrobial agents

4.7 Glossary

Acid: Any substance that in water solution tastes sour, changes blue litmus paper to red, reacts with some metals to liberate hydrogen, reacts with bases to form salts, and promotes chemical reactions (acid catalysis).

Additive: A substance added to something in small quantities to improve or preserve it

Agent: Is something that produces or is capable of producing an effect

Antimicrobial: A substance produced by one living organism that kills or inhibits the growth of another.

Antioxidants: They are substances that can prevent or slow damage to cells caused by free radicals, unstable molecules that the body produces as a reaction to environmental and other pressures.

Applications: The act of putting to a special use or purpose

Artistic: Is something considered to be aesthetically satisfying that is creative or that requires a special art or craft skill

Autoxidation: Is oxidation by direct combination with oxygen (as in air) at ordinary temperatures.

Base: Any substance that in water solution is slippery to the touch, tastes bitter, changes the colour of indicators (e.g., turns red litmus paper blue), reacts with acids to form salts, and promotes certain chemical reactions (base catalysis).

Biosynthesis: Is a multi-step, enzyme-catalyzed process where substrates are converted into more complex products in living organisms.

Catalyzed: To modify, especially to increase, the rate of a chemical reaction through the action of a catalyst

Colorants: A dye, pigment, or other substance that colours something

Creation: The action or process of bringing something into existence.

Dosage: A dose is a measured quantity of a medicine, nutrient, or pathogen which is delivered as a unit.

Enhancer: A substance or a device which makes a particular thing look, taste, or feel better.

Enzymes: Enzymes are proteins that help speed up metabolism, or the chemical reactions in our bodies. They build some substances and break others down

Flavoring: Is a substance that gives another substance taste, altering the characteristics of the solute, causing it to become sweet, sour, tangy, etc.

Food: Any nutritious substance that people or animals eat or drink or that plants absorb in order to maintain life and growth.

Function: The action for which a person or thing is specially fitted or used or for which a thing exists

Intake: An amount of food, air, or another substance taken into the body

Legislation: Is the process or product of enrolling, enacting, or promulgating law by a legislature, parliament, or analogous governing body

Mutagenicity: Refers to the induction of permanent transmissible changes in the amount or structure of the genetic material of cells or organisms

Natural: In or derived from nature; not made or caused by humankind

Nutritive: Containing many of the substances needed for life and growth

Organic: Relating to or obtained from living things organic matter

Oxidation: Is a process in which a chemical substance changes because of the addition of oxygen.

Pigments: A substance that gives something a particular colour when it is present in it or is added to it

Physiological: Characteristic of or appropriate to an organism's healthy or normal functioning

Preservative: It is a substance or a chemical that is added to products such as food products, beverages, pharmaceutical drugs, paints, biological samples, cosmetics, wood, and many other products to prevent decomposition by microbial growth or by undesirable chemical changes

Psychological: Of, pertaining to, dealing with, or affecting the mind, especially as a function of awareness, feeling, or motivation

Quality Control: A system of maintaining standards in manufactured products by testing a sample of the output against the specification.

Raw Materials: They are the input goods or inventory that a company needs to manufacture its products.

Regulations: Are rules made by a government or other authority in order to control the way something is done or the way people behave.

Safety: The state of being safe; freedom from the occurrence or risk of injury, danger, or loss.

Salt: Any chemical compound formed from the reaction of an acid with a base, with all or part of the hydrogen of the acid replaced by a metal or other cation.

Scientific: Based on or characterized by the methods and principles of science.

Stability: situation with no unexpected or harmful changes; ability to remain balanced and not fall; substance's ability to stay in the same state

Subchronic: In human health and disease, of moderate or intermediate duration

Sweeteners: Sweeteners are food additives used as substitutes for sugar, mainly sucrose and fructose

Synergistic: Relating to the interaction or cooperation of two or more organizations, substances, or other agents to produce a combined effect greater than the sum of their separate effects.

Synthetic: A compound made artificially by chemical reactions

Teratology: The study of malformations or serious deviations from the normal type in developing organisms

Toxicity: It is the degree to which a chemical substance or a particular mixture of substances can damage an organism

Toxicology: The study of all the adverse effects resulting from the interaction of chemicals or physical agents with living organisms.

Usage: Is the degree to which something is used or the way in which it is used

Utilization: The action of making practical and effective use of something.

4.8 References/Further Reading

Food Additives Second Edition Revised and Expanded edited by A. Larry Branen, P. Michael Davidson, Seppo Salminen, John H. Thorngate III. Marcel Dekker, Inc. New York, Basel. Retrieved from

http://ariefm.lecture.ub.ac.id/files/2012/10/A._Larry_Branen_P._Michael_Davidson_Seppo_SalmiBookFi.org-FOOD-ADDITIVES.pdf

https://www.britannica.com/topic/food-additive/Preservatives

4.9 Possible Answers to Self-Assessment Exercise

Self-Assessment Exercise 1

1. Food preservatives are classified into two main groups: antioxidants and antimicrobials.

2.

Table 1
Food preservatives

chemical agent	mechanism of action
Antioxidants	
ascorbic acid	oxygen scavenger
butylated hydroxyanisole (BHA)	free radical scavenger
butylated hydroxytoluene (BHT)	free radical scavenger
citric acid	enzyme inhibitor/metal chelator
sulfites	enzyme inhibitor/oxygen scavenger
tertiary butylhydroquinone (TBHQ)	free radical scavenger
tocopherols	free radical scavenger
Antimicrobials	
acetic acid	disrupts cell membrane function (bacteria, yeasts, some molds)
benzoic acid	disrupts cell membrane function/inhibits enzymes (molds, yeasts, some bacteria)
natamycin	binds sterol groups in fungal cell membrane (molds, yeasts)
nisin	disrupts cell membrane function (gram-positive bacteria, lactic acid-producing bacteria)
nitrates, nitrites	inhibits enzymes/disrupts cell membrane function (bacteria, primarily Clostridium botulinum)
propionic acid	disrupts cell membrane function (molds, some bacteria)
sorbic acid	disrupts cell membrane function/inhibits enzymes/inhibits bacterial spore germination (yeasts, molds, some bacteria)
sulfites and sulfur dioxide	inhibits enzymes/forms addition compounds (bacteria, yeasts, molds)

Self-Assessment Exercise 2

1. The two principal types of oxidation that contribute to food deterioration are autoxidation of unsaturated fatty acids (i.e., those containing one or more double bonds between the carbon atoms of the hydrocarbon chain) and enzyme-catalyzed oxidation.
2. Based on their occurrence, antioxidants are categorized as natural or synthetic

i. Natural: They are classified as chain-breaking antioxidants, which react with radicals and convert them into more stable products. Generally, antioxidants of this group are phenolic in structure and include the following: Antioxidant minerals, Antioxidant vitamins and Phytochemicals

ii. Synthetic: These are phenolic compounds that carry out the role of capturing free radicals and stopping the chain reaction. These compounds include butylated hydroxyl anisole (BHA), butylated hydroxyltoluene (BHT), propyl gallate (PG), metal chelating agent (EDTA), tertiary butyl hydroquinone (TBHQ), and nordihydroguaiaretic acid (NDGA).

Self-Assessment Exercise 3

1. In selecting a food antimicrobial agent, several factors must be taken into consideration. First, the antimicrobial spectrum of the compound to be used must be known. This, along with knowledge of the bioburden of the food product, will allow the use of correct antimicrobial agent for the microorganism(s) of concern. Second, the chemical and physical properties of both the antimicrobial and the food product must be known. Such factors as pKa and solubility of the antimicrobial and the pH of the food will facilitate the most efficient use of an antimicrobial. Third, the conditions of storage of the product and interactions with other processes must be evaluated to ensure that the antimicrobial will

remain functional over time. Fourth, a food must be of the highest microbiological quality initially if an antimicrobial is to be expected to contribute to its shelf-life. Finally, the toxicological safety and regulatory status of the selected compound must be known.

2. Food antimicrobial agents: Dimethyl Dicarbonate, Lysozym, Natamycin, Nisin, Nitrites, Organic Acids, Acetic Acid and Acetate Salts, Benzoic Acid and Benzoates, Lactic Acid and Lactates, Propionic Acid and Propionates, Sorbic Acid and Sorbates, Parabens, Phosphates, Sulfites, e.t.c.

UNIT 5 CHEMICAL PRESERVATIVES: ANTIBROWNING, EMULSIFIERS, SEQUESTERING AND BUFFERING AGENTS

CONTENTS

5.1 Introduction

Chemical food preservatives are substances which, under certain conditions, either delay the growth of microorganisms without necessarily destroying them or prevent deterioration of quality during manufacture and distribution.

In this unit, you shall explore chemical preservatives: antibrowning, emulsifiers, sequestering and buffering agents

5.2 Learning Outcomes

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

- discuss what is meant by undesirable browning
- discuss enzymatic and non-enzymatic browning
- discuss sulfites as browning inhibitors
- discuss what emulsifiers are
- discuss sequestering and buffering agents
- analyse the categorises of food emulsifiers

5.3 Undesirable Browning

Introduction- Many plant foods are subject to degradative reactions during handling, processing, or storage, collectively described as browning reactions, that result in the formation of brown, black, gray, or red coloured pigments. Such reactions are generally grouped into two categories: enzymatic browning and nonenzymatic browning. Examples of the former include browning of cut apples or potatoes, while examples of the latter include browning of shelf-stable, pasteurized juices and dehydrated vegetables.

- **Enzymatic Browning**

Enzymatic browning results from the oxidation of polyphenols to quinones, catalyzed by the enzyme polyphenol oxidase (E.C. 1.14.18.1 and E.C. 1.10.3.1; also known as PPO, tyrosinase, o-diphenol oxidase, and catechol oxidase), and subsequent further reaction and polymerization of the quinones. This discoloration is generally a problem with raw fruit and vegetable products rather than blanched or thermally processed products since enzymes would be inactivated in the latter. Enzymatic browning of raw commodities may result from physiological injury; senescence; pre- or postharvest bruising; disruption of the fruit or vegetable flesh by peeling, coring, slicing, or juicing; tissue disruption from freeze–thaw cycling; and tissue disruption by bacterial growth. The occurrence of enzymatic browning can limit the shelf-life of fresh-cut fruits and salad vegetables, fresh mushrooms, prepeeled potatoes, yam, unripe plantains and other fresh products of commercial importance. This problem has held back the development and commercialization of fresh-cut fruits such as sliced apples. Enzymatic browning also may be a problem with some dehydrated and frozen fruits and vegetables. In addition to causing discoloration, enzymatic browning reactions in fruit and vegetable products also can result in loss of ascorbic acid (vitamin C) through reaction with quinones. Enzymatic browning is usually controlled by blanching, where applicable; acidification; and application of sulfites (which are now subject to regulatory constraints with a number of commodities) or sulfite substitutes such as ascorbic acid or cysteine. These substitutes are generally less effective than sulfites.

- **Nonenzymatic Browning**

Nonenzymatic browning reactions may result from the classic Maillard reaction between carbonyl and free amino groups, i.e., reducing sugars and amino acids, which produces melanoidin pigments in a wide variety of foods including dairy, cereal, fruit, and vegetable products. Such discolorations generally occur in products that are subjected to heat and/or prolonged storage. Nonenzymatic browning can be minimized by avoidance of excessive exposure to heat, control of moisture content in dehydrated products, and application of sulfites.

- **Sulfites as Browning Inhibitors**

Sulfites are unique in their ability to perform a number of useful functions as food additives—control of both enzymatic and nonenzymatic browning, suppression of microbial growth, and bleaching. They have been used since antiquity for these and other purposes. In the case of enzymatic browning, sulfites act as Polyphenoloxidase inhibitors and also react with intermediates to prevent pigment formation. Sulfites inhibit nonenzymatic browning by reacting with carbonyl intermediates, thereby blocking pigment formation.

Treatment conditions vary widely. Sulfite may be applied as sulfur dioxide; sulfurous acid; or sodium (or potassium) sulfite, bisulfite, or metabisulfite. Treatment levels vary widely, but treatment residues usually do not exceed several hundred ppm, although some products may contain 1000 ppm. Among the products that are treated with sulfites are dehydrated fruits and vegetables, prepeeled potatoes, fresh grapes, and wine. Maximum levels of 300, 500, and 2000 ppm have been proposed for fruit juices, dehydrated potatoes, and dried fruit, respectively (FDA, 1988b).

- **Safety and Regulatory Issues**

Sulfite residues in foods have been responsible for some severe allergic reactions in susceptible individuals, usually asthmatics. Fatal anaphylactic reactions have been reported. The FDA has restricted use of sulfites in certain categories of foods where there is no means of alerting sensitive consumers to their presence. Fruit and vegetable products that are consumed raw and sold unlabeled in salad bars, restaurants, or from bulk containers so that the consumer cannot be alerted to their presence fall in this category. FDA established labeling requirements for foods containing sulfites and affirmed the GRAS status of sulfiting agents in 1988.

Conventional Alternative to Sulfite

1) Ascorbic Acid Based Formulations

Ascorbic acid (vitamin C) has been used as an antibrowning agent for more than five decades and is still the most widely used alternative to sulfiting agents. The chemical basis for the efficacy of ascorbic acid treatments is the ability of ascorbic acid to reduce quinones, produced by PPO-catalyzed oxidation of polyphenols, back to dihydroxy polyphenols. As long as quinones do not accumulate, further reactions leading to pigment formation are avoided. When the added ascorbic acid is depleted quinones will accumulate, and browning will result. Thus, the primary effect of ascorbic acid is as an inhibitor of the enzymatic browning reaction, not as an inhibitor of PPO per se.

2) Cysteine

This alternative to sulfites is a key ingredient of browning inhibitor formulations for apples and prepeeled potatoes supplied by EPL Technologies, Inc. Cysteine reacts with quinone intermediates, formed by PPO-catalyzed oxidation of polyphenols, to yield stable, colorless compounds, thereby blocking pigment formation. Cysteine also directly inhibits the enzyme.

3) 4-Hexylresorcinol

This PPO inhibitor is used commercially to control discoloration of unpeeled shrimp (Everfresh) and is highly effective as a browning inhibitor for some fruits and vegetables.

Self-Assessment Exercises 1

1. Differentiate between the two types of browning reaction
2. How do sulfites prevent browning?

5.4 Emulsifiers

An emulsion is a heterogeneous system, consisting of at least one immiscible liquid intimately dispersed in another in the form of droplets, whose diameter, in general, exceeds 0.1 µm. Such systems possess a minimal stability, which may be accentuated by such additives as surface-active agents, finely divided solids, etc. In an emulsion, liquid droplets and/or liquid crystals are dispersed in a liquid.

Emulsifiers are added to increase product stability and attain an acceptable shelf-life. The function of an emulsifier is to join together oily and aqueous phases of an emulsion in a homogeneous and stable preparation. The main characteristic of an emulsifier is that it contains in its molecule two parts. The first part has a hydrophilic affinity, while the second has a lipophilic affinity. Emulsifiers are generally classified as anionic emulsifiers, cationic emulsifiers, amphoteric emulsifiers, and nonionic emulsifiers.

Emulsifier selection is based upon final product characteristics, emulsion preparation methodology, the amount of emulsifier added, the chemical and physical characteristics of each phase, and the presence of other functional components in the emulsion. Food emulsifiers have a wide range of functions. The most obvious is to assist stabilization and formation of emulsions by the reduction of surface tension at the oil–water interface. The most common examples are mayonnaise and margarine. An additional function is that of alteration of the functional properties of other food components. An example of this is the use of emulsifiers in bakery products such as a crumb softener and dough conditioner. A third function is to modify the crystallization of fat, e.g., the reduction of bloom in certain candy products.

5.4.1 Categories of Food Emulsifiers

Food emulsifiers can be categorized (Table 1) on the basis of several characteristics including origin, either synthetic or natural; potential for ionization, nonionic versus ionic; hydrophilic/lipophilic balance (HLB); and the presence of functional groups.

Table 1 Food Emulsifier Categories

Lecithin and lecithin derivatives
Glycerol fatty acid esters
Hydroxycarboxylic acid and fatty acid esters
Lactylate fatty acid esters
Polyglycerol fatty acid esters
Ethylene or propylene glycol fatty acid esters
Ethoxylated derivatives of monoglycerides
Sorbitan fatty acid esters
Miscellaneous derivatives

- ***Sorbitol or Sorbitan esters***

Sorbitol or sorbitan esters are formed from 1,4-anhydro-sorbitol and fatty acids. Typically, the emulsifier consists of a mixture of stearic and palmitic acid esters of sorbitol and its mono- and dianhydrides (Fig. 1)

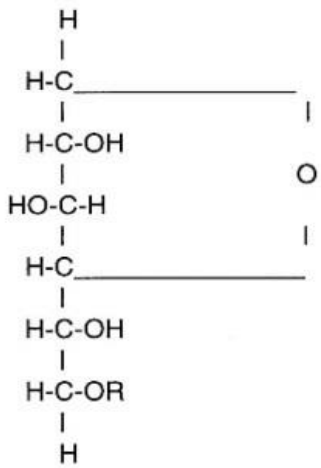

Figure 1 Sorbitan stearate, where R represents a fatty acid moiety, for example, stearic acid, oleic acid, lauric acid, or palmitic acid.

- ***Lactitol***

Lactitol (the hydrogenation product of lactose) palmitate is synthesized by direct esterification at a temperature of approximately 160°C.

- ***Sucrose fatty acid ester***

Sucrose fatty acid esters (Fig. 2) can be synthesized using a variety of solvents or by direct esterification.

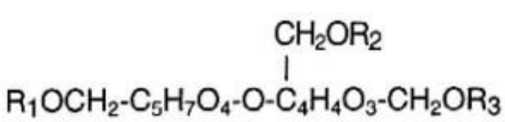

Figure 2 Sucrose fatty acid esters, where at least one of either R_1, R_2, or R_3 represents a fatty acid and the reminder may represent a fatty acid or a hydrogen; the degree of substitution is 1–3.

5.4.2 Applications in Food

Emulsifiers have a wide range of functional properties in addition to the obvious one: stabilization of food emulsions. Table 2 is a list of functional properties of food emulsifiers compiled from a variety of sources including product brochures from several emulsifier manufacturers.

Table 2 Functional Properties of Food Emulsifiers

Functions	Product examples
Emulsification, water-in-oil emulsions	Margarine
Emulsification, oil-in-water emulsions	Mayonaise
Aeration	Whipped toppings
Whippability	Whipped toppings
Inhibition of fat crystallization	Candy
Softening	Candy
Antistaling	Bread
Dough conditioner	Bread dough
Improve loaf volume	Bread
Reduce shortening requirements	Bread
Pan-release agent	Yeast-leavened and other dough and batter products
Fat stabilizer	Food oils
Antispattering agent	Margarine and frying oils
Antisticking agent	Caramel candy
Protective coating	Fresh fruits and vegetables
Surfactant	Molasses
Control viscosity	Molten chocolate
Improved solubility	Instant drinks
Starch complexation	Instant potatoes
Humectant	Cake icings
Plasticizer	Cake icings
Defoaming agent	Sugar production
Stabilization of flavor oils	Flavor emulsions
Promotion of ''dryness''	Ice cream
Freeze–thaw stability	Whipped toppings
Improve wetting ability	Instant soups
Inhibition of sugar crystallization	Panned coatings

a) Cereal-based Products

With bakery products, emulsifiers not only improve final product characteristics, but also facilitate processing. First of all, emulsifiers can function as dough conditioners. Certain emulsifiers also function as crumb softeners, another type of dough conditioner. Emulsifiers can form complexes with amylose that are difficult to dissociate. Emulsifiers can affect both starch viscosity and gelatinization.

b) Dairy Products

Ice cream is both a frozen foam and an emulsion. Protein and polar lipids (lecithin) found in milk function as surfactants in ice cream. However, these naturally occurring components are usually supplemented with additional emulsifiers to make ice cream. Emulsifiers in ice cream improve fat dispersion, facilitate fat–protein interactions, control fat agglomeration, facilitate air incorporation, impart dryness to formed products, confer smoother texture due to smaller ice crystals and air cells, increase resistance to shrinkage, reduce whipping time, and improve melt-down.

c) Candy Products

The elimination of ‘‘bloom,’’ i.e., the transition of fat crystals from the alpha and beta′ configuration to the less desirable beta configuration, is a key reason for the addition of emulsifiers to candy products. Emulsifiers can be used as crystal structure modifiers in mixtures of triglycerides. Certain emulsifiers can also be used to control product viscosity in cream fillings and in chocolates.

d) Others (Miscellaneous)

Emulsifiers have been utilized in the production of meat analog products; in the formulation of flavour emulsions too.

- **Lecithin and Lecithin Derivatives**

The primary source of lecithin, the only naturally occurring emulsifier used in any significant quantity in the food industry, is soybeans. Soybean oil contains anywhere from 1– 3% phospholipids in the crude oil. Other, less significant, sources include corn, sunflower, cottonseed, rapeseed, and eggs.

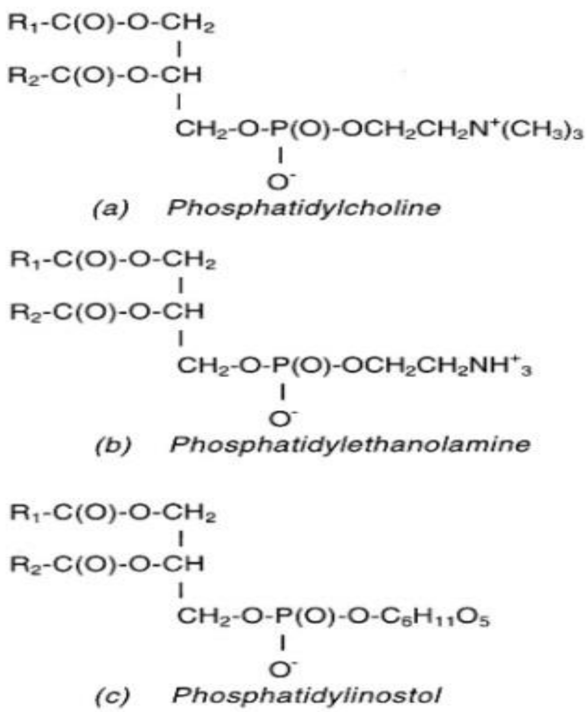

Figure 3 The primary phospholipids reported in commercial lecithin, where R_1 and R_2 are fatty acids.

- **Mono- and Diglycerides**

Mono- and diglycerides are the most commonly used food emulsifiers (Fig. 4). They consist of esters synthesized via catalytic transesterification of glycerol with triglycerides, with the usual triglyceride source of hydrogenated soybean oil.

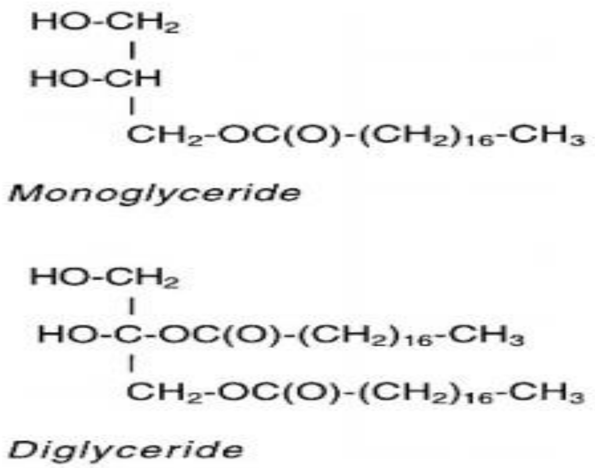

Figure 4 Mono- and diglycerides.

- **Hydroxycarboxylic and Fatty Acid Esters**

To produce an emulsifier with increased hydrophilic character relative to monoglycerides, small organic acids are esterified to monoglycerides (Fig. 5). Some of the acids used are acetic, citric, fumaric, lactic, succinic, and tartaric.

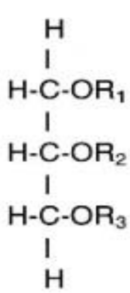

Figure 5 Organic acid ester of monoglyceride, where at least one R is a short chain organic acid, for example, acetic acid.

- **Lactylate Fatty Acid Esters**

Polymeric lactic acid esters of monoglycerides (Fig. 6) are also available, commonly known as sodium or calcium stearoyl-2-lactylates. Typically, there are two lactic acid groups per emulsifier molecule.

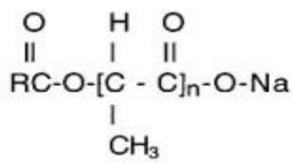

Figure 6 Sodium stearoyl-2-lactylate, where n normally averages 2 and R is a fatty acid moiety.

- **Polyglycerol Fatty Acid Esters**

Polyglycerol esters of fatty acid (Fig. 7) are also used in food products, primarily in baked goods. They consist of mixed partial esters synthesized from the reaction of polymerized glycerol with edible fats.

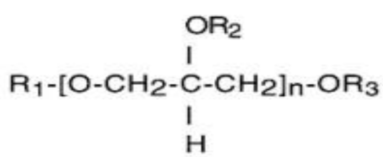

Figure 7 Polyglycerol esters of fatty acids, where R_1, R_2, and R_3 are each either a fatty acid and/or a hydrogen and where the average value of n is greater than 1.

- **Polyethylene or Propylene Glycol Fatty Acid Esters**

Fatty acids can be esterified directly to polyethylene glycol ethers (Fig. 8) or by enzymatic preparation, which allows better control of the reaction.

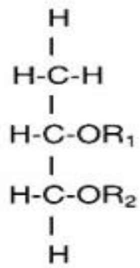

Figure 8 Propylene glycol esters of fatty acids, where R_1 and R_2 represent either a fatty acid and/or a hydrogen and where at least one R represents a fatty acid.

- **Ethoxylated Derivatives of Monoglycerides**

Ethoxylated mono- and diglycerides are produced from the reaction of several moles of ethylene oxide and mono- or diglycerides under pressure. Ethoxylation of monoglycerides results in a product that is much more hydrophilic relative to monoglycerides.

Polyoxyethylene monoglycerides may contain as many as 40 moles of ethylene oxide per mole of monoglyceride. The end product of the synthesis is actually a mixture with a distribution range and peak; therefore, lots often vary among manufacturers.

- **Sorbitan Fatty Acid Esters**

Polyoxyethylene sorbitan esters are synthesized by the addition, via polymerization, of ethylene oxide to sorbitan fatty acid esters. These nonionic hydrophilic emulsifiers (Fig. 9) are very effective antistaling agents and, thus, are used in a wide variety of bakery products

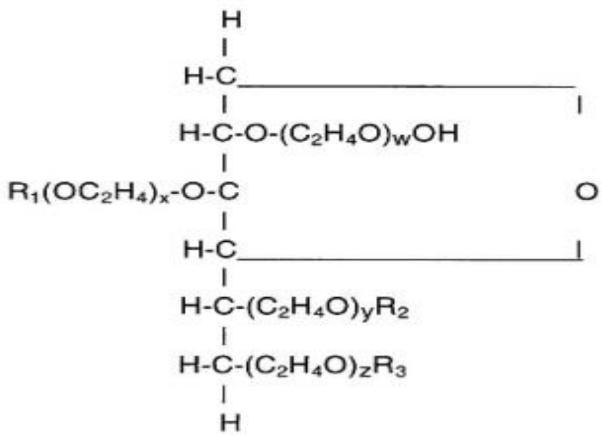

Figure 9 Polysorbates, where w + x + y + z = 20 (approximately) and Rs represent a single fatty acid and hydrogens for polysorbate 20, 40, 60, and 80. For polysorbate 65, each R represents a stearic acid moiety. The fatty acids are lauric, palmitic, stearic, and oleic acid for polysorbate 20, 40, 60, and 80, respectively.

- **Miscellaneous Derivatives**

Fatty acids can be esterified directly to compounds other than glycerol, for example, sugar alcohols, like sorbitol, mannitol, and maltitol, and sugars, like sucrose, glucose, fructose, lactose, and maltose.

5.4.3 Toxicology and Worldwide Regulations concerning use

There are two sources of international food standards, the Codex Alimentarius standards under the auspices of the Food and Agricultural Organization/World Health Organization (FAO/WHO) on a worldwide basis and the European Economic Community (EEC) directives applicable to the member states within the European Economic Community (Gnauck, 1978). In the United States the Food and Drug Administration (FDA) is the primary source of regulation on food, particularly for food additives.

Recommendations for the Codex Alimentarius Committee come from the Joint Expert FAO/WHO Committee on Food Additives (JEFCA), for the EEC from the Scientific Committee on Food (SCF), and in the United States from within the FDA. Opinions from the SCF and the JEFCA are provided to legislative bodies in interested countries either in Europe or elsewhere in the world.

Self-Assessment Exercises 2

1. What is an emulsion?
2. State the Categories of Food Emulsifiers
3. What is the characteristics of emulsifier?

5.5 Sequestering and Buffering Agents

Food products are open to deterioration, discoloration, and rancidity because of reactions of trace metals like iron, nickel, and copper on foods. Even if the concentration is very minute and as low as 0.05ppm metal ions can cause rancidity, discoloration and cause spoilage in texture, odour or flavour. Ascorbic acid, vitamin E, thiamine and folic acid are affected by copper and both copper and iron can destroy vitamin A in fortified foods. Even fats and oils can get oxidized through metal ions as they act as catalysts. This shortens the shelf life of processed food products.

Sequestering agents have become important for the food processing industry as they prevent spoilage in foods. Sequestering agents surround the metal ions so that they cannot react to food to cause food deterioration. In other words, they form a buffer between the metal ions and the food to prevent it from spoilage during processing and storage.

Sequestering agents are used in foods so that they can stabilize the product and prevent deterioration in food colour and aroma. When sequestering agents bind with the trace elements they also increase antioxidant efficacy which prevents the oxidation of ascorbic acid and also of the fat-soluble vitamins. Sequestering and buffering agents, therefore, protect the natural flavour, colour, texture, and nutrition in food products. They improve shelf life and the products have more appeal. Beverages and other foods with liquid contents will not have loss of clarity and there will be no deterioration of texture in solid foods.

According to Heath Canada sequestering agents are substances that *"combine with metallic elements in food, thereby preventing their taking part in reactions leading to colour or flavour deterioration. For example, the addition of a sequestrant to canned lima beans prevents darkening of the product because the iron ions and other trace metals in the canning water are bound by the additive and consequently are unavailable for other reactions."*

Regulations for Sequestering and buffering Agents (Acids, Bases, and Salts)

- **"Sequestering agents**" means substances which prevent the adverse effect of metals catalyzing the oxidative break-down of foods forming chelates; thus inhibiting decolorization, off taste and rancidity.
- **"Buffering agents"** means materials used to counter acidic and alkaline changes during storage or processing steps, thus improving the flavour and increasing the stability of foods.

Restrictions on the use of sequestering and buffering agents

TABLE

S/NO.	Name of sequestering and buffering agents	Group of Food	The maximum level of use (parts per Million) (ppm)(mg./kg)
	(1)	**(2)**	**(3)**
1.	Acetic Acid	(i) Acidulant, buffering and neutralizing agents in beverages-soft drinks (ii) in canned baby foods	Limited by GMP 5000
2.	Adipic acid	Salt substitute and dietary food	250
3.	Calcium Gluconate	In confections	2,500
4.	Calcium Carbonate	As a neutralizer in number of foods	10,000
5.	Calcium oxide	As a neutralizer in specified dairy product	2,500
6.	Citric acid malic acid	Carbonated beverage and as an acidulant in miscellaneous foods	Limited by G.M.P
7.	DL-Lactic Acid (food grade)	As acidulant in miscellaneous foods	Limited by G.M.P
8.	(L+) Lactic Acid (food	As acidulant in miscellaneous	Limited by G.M.P

	grade)	foods	
9.	Phosphoric acid	Beverage, soft drinks	600
10.	Polyphosphate containing less than 6 Phosphate moieties	(a) Processed cheese, bread (b) Milk Preparations (c) Cake Mixes (d) Protein foods	40,000 4,000 10,000 4,000
11.	(L+) Tartaric	Acidulants	600
12.	Calcium Disodium, Ethylene, Diamine tetraacetate	(i) Emulsions containing refined vegetable oils, eggs, vinegar, salt, sugar, and spices; (ii) Salad dressing; (iii) sandwich spread or fat spread	50
13.	Fumaric acid	As acidulant in Miscellaneous	3000ppmm

NOTE: - DL-Lactic acid and L(+) Tartaric acid shall not be added to any food meant for children below 12 months (The lactic acid shall also conform to the specification laid down by the Nigerian Standards Institution.)

Self-Assessment Exercises 3

1. What are sequestering agents and buffering agents
2. Enumerate the usefulness of sequestering agents to the food and beverage industry

5.6 Summary

Anti-browning agents are compounds that act primarily on either the enzyme or the intermediates of pigment formation. Their use in the food industry is constrained by issues such as toxicity, cost, and effects on taste, texture and colour

Products enriched with emulsifiers are often called velvety, delicate and creamy. Emulsifier selection is based upon final product characteristics, emulsion preparation methodology, the amount of emulsifier added, the chemical and physical characteristics of each phase, and the presence of other functional components in the emulsion.

Sequestering and buffering agents, improve shelf life of products making them more appealing.

In this unit, you examined various chemical preservatives: antibrowning, emulsifiers, sequestering and buffering agents, their applications and restrictions in useage.

5.7 References/Further Reading

Food Additives Second Edition Revised and Expanded edited by A. Larry Branen, P. Michael Davidson, Seppo Salminen, John H. Thorngate III. Marcel Dekker, Inc. New York, Basel. Retrieved from
http://ariefm.lecture.ub.ac.id/files/2012/10/A._Larry_Branen_P._Michael_Davidson_Seppo_SalmiBookFi.org-FOOD-ADDITIVES.pdf

https://foodsafetyhelpline.com/what-are-sequestering-and-buffering-agents-what-do-fssai-regulations-say/

1.8 Possible Answers to Self-Assessment Exercise

Self-Assessment Exercises 1

1. Browning reactions are generally grouped into two categories: enzymatic browning and nonenzymatic browning. Enzymatic browning results from the oxidation of polyphenols to quinones, catalyzed by the enzyme polyphenol oxidase (E.C. 1.14.18.1 and E.C. 1.10.3.1; also known as PPO, tyrosinase, o-diphenol oxidase, and catechol oxidase), and subsequent further reaction and polymerization of the quinones. While Nonenzymatic browning reactions may result from the classic Maillard reaction between carbonyl and free amino groups, i.e., reducing sugars and amino acids, which produces melanoidin pigments in a wide variety of foods including dairy, cereal, fruit, and vegetable products.
2. Sulfites are unique in their ability to perform a number of useful functions as food additives—control of both enzymatic and nonenzymatic browning, suppression of microbial growth, and bleaching. In the case of enzymatic browning, sulfites act as Polyphenoloxidase inhibitors and also react with intermediates to prevent pigment formation. Sulfites inhibit nonenzymatic browning by reacting with carbonyl intermediates, thereby blocking pigment formation.

Self-Assessment Exercises 2

1. An emulsion is a heterogeneous system, consisting of at least one immiscible liquid intimately dispersed in another in the form of droplets, whose diameter, in general, exceeds 0.1 µm. Such systems possess a minimal stability, which may be accentuated by such additives as surface-active agents, finely divided solids, etc. In an emulsion, liquid droplets and/or liquid crystals are dispersed in a liquid.
2. The main characteristic of an emulsifier is that it contains in its molecule two parts. The first part has a hydrophilic affinity, while the second has a lipophilic affinity.

Self-Assessment Exercises 2

1. An emulsion is a heterogeneous system, consisting of at least one immiscible liquid intimately dispersed in another in the form of droplets, whose diameter, in general, exceeds 0.1 µm. Such systems possess a minimal stability, which may be accentuated by such additives as surface-active agents, finely divided solids, etc. In an emulsion, liquid droplets and/or liquid crystals are dispersed in a liquid.
2.
3.

Table 1 Food Emulsifier Categories

Lecithin and lecithin derivatives
Glycerol fatty acid esters
Hydroxycarboxylic acid and fatty acid esters
Lactylate fatty acid esters
Polyglycerol fatty acid esters
Ethylene or propylene glycol fatty acid esters
Ethoxylated derivatives of monoglycerides
Sorbitan fatty acid esters
Miscellaneous derivatives

3. The main characteristic of an emulsifier is that it contains in its molecule two parts. The first part has a hydrophilic affinity, while the second has a lipophilic affinity.

Self-Assessment Exercises 3

1. "Sequestering agents" means substances which prevent the adverse effect of metals catalyzing the oxidative break-down of foods forming chelates; thus inhibiting decolorization, off taste and rancidity. "Buffering agents" means materials used to counter acidic and alkaline changes during storage or processing steps, thus improving the flavour and increasing the stability of foods.
2. Sequestering agents are used in foods so that they can stabilize the product and prevent deterioration in food colour and aroma. When sequestering agents bind with the trace elements they also increase antioxidant efficacy which prevents the oxidation of ascorbic acid and also of the fat-soluble vitamins. Sequestering and buffering agents, therefore,

protect the natural flavour, colour, texture, and nutrition in food products. They improve shelf life and the products have more appeal. Beverages and other foods with liquid contents will not have loss of clarity and there will be no deterioration of texture in solid foods.

MODULE 4

Unit 1 Naturally occurring Toxins: Microbial Toxins

Unit 2 Naturally occurring Toxins: Bacterial and Plant Toxins

Unit 3 Naturally occurring and Environmental Chemical Contaminants

UNIT 1 NATURALLY OCCURRING TOXINS: MICROBIAL TOXINS

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1.2 Learning Outcomes

1.3 Algae

1.3.1 Algae toxins

1.4 Fungal Toxins

1.4.1 Mycotoxins

1.4.2 Mushroom toxins

1.5 Summary

1.6 References/Further Reading

1.7 Possible Answers to Self-Assessment Exercise

1.1 Introduction

Natural toxins are toxin compounds that are naturally produced by living organisms. These toxins are not harmful to the organisms themselves but may be toxic to other creatures, including humans, when eaten.

In this unit you will explore naturally occurring toxins: microbial toxins; algae and fungal toxins

1.2 Learning Outcomes

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

- discuss the most common types of algal toxins caused by shellfish and fish contaminated and their resultant illnesses and the preventive measures to these illnesses
- discuss the most common types of mycotoxins and the mould responsible for it
- discuss the most common types of toxins caused by the various mushrooms

- **Preamble**

Microbial toxins are chemical substances produced naturally by microorganism and are one of the primary concerns in the area of food safety. Microbial toxins are produced by algae, fungi and bacteria.

1.3 Algae

Algae can be unicellular (e.g., most phytoplanktons) or multicellular (e.g., seaweed) and are found in freshwater, marine and terrestrial habitats. Some algae, such as dinoflagellates, produce algal toxins (phycotoxins) that can be harmful to humans. Under certain conditions, the population of algae in an aquatic system can increase rapidly to become an algal bloom, commonly referred to as red tide or blue green algae. Various species of algae are involved in algal blooms, and these species change over time, based on temperature, light, nutrients and other factors. Algal blooms are called Harmful Algal Blooms (HABs) when they pose environmental or health hazards. The blooms occur when water is contaminated by phosphates. During HABs, or as a consequence of bioaccumulation through the marine food chain, the toxins produced by algae may accumulate in a variety of marine organisms, such as the molluscs, crustaceans and finfish, as well as in freshwater fish and shellfish.

1.3.1 Algal Toxins

Algal toxins are tasteless, odourless and heat resistant. The most common algal toxins are saxitoxins, brevetoxins, dinophysistoxins, domoic acid and ciguatoxins. Shellfish and finfish contaminated with these toxins can be potentially harmful to human health, causing a variety of foodborne illnesses such as Paralytic Shellfish Poisoning (PSP), Neurotoxic Shellfish Poisoning (NSP), Diarrheic Shellfish Poisoning (DSP), Amnesic Shellfish Poisoning (ASP) and Ciguatera Fish Poisoning (CFP) (See table 1).

- **Saxitoxins**

Saxitoxins are natural toxins produced by microscopic marine algae found in coastal waters. Saxitoxins may accumulate in the neck (siphon) and the gills of butter clams; in the roe or gonads of scallops, and in the tomalley (also known as hepatopancreas – soft green substance inside the body cavity) of crabs and lobsters. It is recommended that people avoid eating these parts. The consumption of shellfish that contain high levels of saxitoxins can cause Paralytic Shellfish Poisoning in humans (See Table 1). Saxitoxins cannot be destroyed by cooking.

- **Brevetoxins**

Brevetoxins are natural toxins released by Karenia brevis, a marine dinoflagellate formerly known as Gymnodinium breve and Ptychodiscus brevis. These toxins, which are tasteless, odourless and resistant to heat and acid, are toxic to fish, marine mammals, birds and humans but not to shellfish such as oysters and mussels. The consumption of raw or under-cooked shellfish that have accumulated high levels of brevetoxins can cause Neurotoxic Shellfish Poisoning in humans (see Table 1).

- **Dinophysistoxins**

Dinophysistoxins are natural toxins produced by dinoflagellates belonging to the genus, Dinophysis, and the genus, Prorocentrum. In humans, they can cause Diarrhetic Shellfish Poisoning (see Table 1), a gastrointestinal illness associated with the ingestion of contaminated bivalves, such as mussels, scallops and oysters.

- **Domoic Acid**

Domoic acid, a naturally occurring toxin, is found in some marine algae of the genus Pseudo-nitzschia, particularly Pseudo-nitzschia pungens. Domoic acid is a neurotoxin that cannot be destroyed by cooking or freezing and that accumulates in filter-feeding, bivalve shellfish such as clams mussels, oysters and scallops. People may be at risk for Amnesic Shellfish Poisoning if they eat shellfish that contain high levels of domoic acid.

Table 1 lists the most common types of food poisoning caused by shellfish and fish contaminated with algal toxins, as well as the preventive measures that can be followed in order to prevent such food poisoning.

Table 1. Algal toxins in shellfish and finfish

Saxitoxin

ILLNESS	Symptoms in humans (individuals experiencing any of these symptoms should seek medical attention immediately)	Reaction time	Associated finfish and shellfish
Paralytic Shellfish Poisoning – PSP	In mild cases may experience: • tingling sensation or numbness around the lips (which slowly spreads to the face and neck), prickly sensation in the fingertips and toes, headache, and dizziness In severe cases may experience: • Incoherent speech, prickly sensations in the arms and legs, stiffness and uncoordinated movement, weakness, rapid pulse, difficulty breathing, salivation, temporary blindness, nausea, and vomiting. In extreme cases may experience: • paralysis of respiratory muscles,	Usually within a few minutes (5to 30) to10 hours after ingestion	Oysters, scallops (e.g., pink, spiny, and purple hinge rock scallops),clams (e.g., butter clams, razor clams, and little neck clams),mussels (e.g., blue mussels), cockles, whelks, and tomalley

	which may lead to respiratory arrest and death within 2 to12 hours after eating contaminated shellfish		(hepatopancreas) of crustaceans such as crabs and lobsters
Preventive Measures	• Do not harvest or eat shellfish from closed areas or areas prone to hazardous algal blooms • Obtain shellfish from a reliable supplier • Uncooked shellfish should be refrigerated or frozen until ready to be prepared • Do not eat shellfish such as clams and scallops that do not open during cooking	• Because of the possibility of the accumulation of saxitoxin, Health Canada recommends that lobster tomalley (hepatopancreas) be eaten in small quantities: no more than the amount from one cooked	lobster daily for adults and no consumption of lobster tomalley by children

Brevetoxins

ILLNESS	Symptoms in humans (individuals experiencing any of these symptoms should seek medical attention immediately)	Reaction time	Associated finfish and shellfish
Neurotoxic Shellfish Poisoning – NSP	May experience: • gastrointestinal symptoms (diarrhea, nausea, vomiting) • respiratory symptoms (shortness of breath, reduction of respiratory rate)	Usually within 30 minutes to24 hours after ingestion	Mussels, oysters scallops, and clams

	• cardiovascular symptoms (hyper/hypotension) • neurological symptoms (sensation of tingling, prickling, numbness of lips, tongue and throat, dizziness, and hot and cold sensations		
Preventive Measures	•Do not harvest or eat shellfish from closed areas or areas prone to *Kerenia brevis blooms*	• Obtain shellfish from are liable source	

Dinophysistoxins

ILLNESS	Symptoms in humans (individuals experiencing any of these symptoms should seek medical attention immediately)	Reaction time	Associated finfish and shellfish
Diarrheic Shellfish Poisoning – DSP	May experience: • diarrhea, nausea, vomiting, and abdominal pain, chills, headache, and fever	Usually within 30 minutes to a few hours (2-3) after ingestion	Mussels, scallops, oysters, and clams
Preventive Measures	• Do not harvest or eat shellfish from closed areas • Obtain shellfish	• Refrigerate and use shellfish within 2-3days or freeze until they are ready to be eaten (followed the recommended refrigeration	

	from a reliable supplier	and freezing times)

Domoic acid

ILLNESS	Symptoms in humans (individuals experiencing any of these symptoms should seek medical attention immediately)	Reaction time	Associated finfish and shellfish
Diarrheic Shellfish Poisoning – DSP	May experience: • nausea, vomiting, diarrhea, muscle weakness, disorientation, and memory loss In severe cases (within 48 hours) may experience: •headache, dizziness, confusion, disorientation, short term memory loss, muscle weakness, seizures, profuse respiratory secretion, cardiac arrhythmias (irregular heartbeat),coma, and possibly death	Usually within 30 minutes to 6 hours after ingestion	Clams (e.g., foot/siphon/mantle of razor clams), mussels, oysters, scallops, and crabs (e.g., viscera of Dungeness crabs)
Preventive Measures	• Do not harvest or eat shellfish from closed areas • Cooking does	• Clean crabs thoroughly by removing all viscera	

	not destroy the toxin

Self-Assessment Exercises 1

1. State the algal toxins you know
2. List some foodborne illnesses caused by algal toxins

1.4 Fungal Toxins

Some moulds and mushrooms have the ability to produce toxins, referred to as mycotoxins, which may cause illnesses (see Tables 2, 3, 4, 5, and 6).

1.4.1 Mycotoxins

Mycotoxins are toxic secondary metabolites produced by fungi found in food (e.g., grains, nut crops, celery, grape juice, and apple juice). The consumption of foods contaminated with mycotoxins can cause mycotoxin poisoning, referred to as mycotoxicosis.

Mycotoxins released by fungi make food unsafe to eat. The production of mycotoxins depends on temperature and moisture, and can occur before or after harvest and during storage, transportation and processing. Because mouldy foods may contain any of the mycotoxins identified in Table 2, they should not be eaten, but should be discarded and destroyed properly.

Some mycotoxins, such as the aflatoxins (named from the fungus, Aspergillus flavus), are carcinogenic, while others may be responsible for kidney and liver damage (ochratoxin A), affect the reproductive function (zearalenone), and interfere with the body's immune system (trichothecenes). The most common types of mycotoxins are aflatoxin, ochratoxin, trichothecenes, patulin, fumonisin, zearalenone and ergot alkaloids.

- **Aflatoxins**

Aflatoxins are produced by three species of Aspergillus and are usually associated with grains or toxins in some mushrooms or toadstool species. They can also be found in milk and milk products from animals that have consumed plants, plant products or animal feed contaminated with the aflatoxin AFB1, which is transformed to AFM1, a less toxic metabolite. Long-term exposure to low levels of aflatoxin in the diet may pose certain health concerns for humans (see Table 2).

- **Ochratoxins**

Ochratoxins are a group of toxic substances produced by the fungus, *Penicillium verrucosum*, and different species of Aspergillus. Ochratoxin can be found in beer and wine, some spices, and also in some foods such as cereals and fresh grapes. Ochratoxins are also produced in grains that have not been properly dried during processing, or have not been properly stored and hence can be found in animal products that have been fed contaminated grains.

- **Trichothecenes**

Trichothecenes are a large group of structurally related mycotoxins, with over 80 identified. Only a few are detected in cereals and grains such as T2- toxin, deoxynivalenol, nivalenol, diacetoxyscirpenol and satratoxins. Acute toxicity varies considerably and T-2 toxin is more toxic than deoxynivalenol. Vomitoxin (deoxynivalenol) and HT-2 toxins, are non-volatile (do not evaporate at normal temperatures and pressures) and are heat-stable.

- **Patulin**

Patulin is a toxic secondary metabolite produced by some species of mould, such as Penicillium and Aspergillus. Apple juice made from bruised or damaged apple is the main source of patulin intake for humans. Patulin can be found mainly in mouldy fruits such as apple and apple products. To reduce exposure to patulin, wash food thoroughly and remove damaged portions before consumption or adding to other foods.

- **Fumonisins**

Fumonisins are produced by fungi such as *Fusarium proliferatun* and *Fusarium verticillioides. Fusarium moniliforme* (*Fusarium verticillioides*) is a common pathogen of corn and is found wherever corn is grown. Kernels that are intact may contain the fungus and the toxin but show no visual signs of the fungal contamination.

- **Zearalenone**

Zearalenone is a toxin excreted by fungi such as *Fusarium culmorum*, and *Fusarium equiseti*. It targets the reproductive organs of animals. Zearalenone needs high humidity and low temperatures to survive, and is found in mouldy cereal crops, such as corn, barley, oats, wheat, rice and sorghum.

- **Ergot Alkaloids**

Ergot is a plant disease caused by the fungus Claviceps purpurea, which produces alkaloids and infects the developing grains of cereals and grasses.

Table 2 lists the organisms responsible for the production of these mycotoxins, the foods in which these toxins can be found, and the symptoms of exposure in humans.

Table 2. Moulds and mycotoxins

MYCOTOXINS	Moulds	Related foods	Symptoms in humans
AIatoxins	Aspergillus flavus, A. parasiticus, A. nomius	Ground nuts, and tree nuts, corn, wheat, bran, flour, peanuts, milk, and milk products	Chronic poisoning may cause: • liver cancer, impaired immune function Acute poisoning may cause: • diminished appetite, malaise, low fever, vomiting, abdominal pain, hepatitis, liver failure (may also affect kidney, spleen, and pancreas), and possibly death
Ochratoxins	Penicillium verrucosum, A. carbonarius (grows at high temp. and can withstand heat and ultraviolet light), A. alliaceus, A. auricomus,	Corn, oats, rye, wheat, coffee beans, spices, wine, grapes, fruits (including vine fruits and dried vine products), and pork	There is insufficient evidence of health effects in humans however, chronic exposure to Ochratoxin A from contaminated foods may cause: • kidney tumours

	A. niger, A. ochraceus		
Trichothecenes	Fusarium sporotrichioides, F. poae, F. equiseti, F. acuminatum	Corn, wheat, millet, barley, cereals, oats, sorghum, and rye	May experience: • mouth and throat inflammation, inflammation of the mucous membrane of the stomach and intestines, vomiting, immunosuppression, skin hemorrhages and necrotic ulcers on the body, headaches, chills, severe nausea, vomiting, and visual disturbances
Patulin	Penicilliumexpansum, Byssochalamyspp, Aspergillus spp	Mouldyfruits (especially apples and apple products made with bruised apples or unfermented apple juice), and vegetables	May cause: • ulceration, congestion, and hemorrhagic lesions (especially in the gastrointestinal tract)
Fumonisins	Fusarium moniliforme, F. proliferatun, F. verticillioides	Corn, corn products (e.g., grits, germ, flour), wheat, and bran	May be linked to: • oesophageal and liver cancer
Zearalenone	F. graminearum, F. culmorum, F. equiseti, F. crookwellense	Mouldy grains, corn, oats, wheat, and barley	• There is inconclusive evidence of health effects in humans
Alkaloids	Claviceps purpurea fungus	Rye, wheat and barley (to a lesser extent)	May cause: • impaired blood circulation, causing alternating burning and freezing sensations, followed by gangrene of

			extremities (referred to as St. Anthony’s fire) • Nervous convulsions may also occur leading to eventual death

1.4.2 Mushroom Toxins

While there are many mushroom species that have been identified, few are able to cause poisoning in humans. Mushroom poisonings are not only caused by natural toxins; the conditions under which mushrooms are handled, packaged, stored and transported can also facilitate bacterial growth.

The toxins released by poisonous mushrooms are produced naturally and cannot be destroyed by cooking, canning or freezing. Mushroom poisoning can be caused by four types of toxins: protoplasmic toxins, neurotoxins, gastrointestinal irritants, and coprine or disulfiram-like toxins.

- **Protoplasmic Toxins**

The consumption of mushrooms that contain protoplasmic toxins, such as amatoxin or orellanine, can cause protoplasmic poisoning. In humans, protoplasmic poisoning causes cell damage and organ failure (e.g., liver and kidney damage). Table 3 highlights the toxins responsible for protoplasmic poisoning, reaction times and associated symptoms.

Table 3. Mushrooms and protoplasmic toxins

TOXINS	Mushrooms	Reaction time	Symptoms in

			humans
Amatoxins	*Amanita phalloides, A. virosa, A. verna* (The green death cap, destroying angel, and fool's mushroom), *Galerina autumnales (Autumn skullcap), G. marginata, Lepiota helveola, L. brunneoincarnata, L. josserandii*	Usually between 8 (or as early as 6) to 12 hours after ingestion	In mild cases may experience: • Vomiting, diarrhea, abdominal pain, and nausea. In severe cases may experience: • Liver failure, coagulation disorders, brain damage, acute renal failure, and death
Hydrazines	*Gyromitra esculenta, G. gigas*	Usually within 6 to 10 hours after ingestion	May experience: • abdominal pain, severe headache, vomiting, diarrhea, liver damage, and damage to the central nervous system and blood cells
Orellanine	*Cortinarius speciocissimus, C. orellanus* (Sorrel webcap)	Usually within 3 to 14 days after ingestion	May experience: • burning thirst, excessive urination, nausea, headache, muscular pain, chills, spasms, and loss of consciousness In severe cases may experience:

			• kidney and liver damage, renal failure, and death

- **Neurotoxins**

Some mushroom species contain neurotoxins (see Table 4), poisons that attack the nervous system and affect, damage or destroy nerve cells. The most common mushroom neurotoxins are muscarine, ibotenic acid/muscimol, and psilocybin. Table 4 lists the mushroom neurotoxins, reaction times and associated symptoms.

Table 4. Mushrooms and neurotoxins

Toxins	Mushrooms	Reaction time	Symptoms in humans
Muscarine	*Inocybe geophylla, I. patouilllardi, I. fastigiata, I. geophylla, C. dealbata, A. muscaria, Boletus, Lactarius*	Usually within 15 to 30 minutes after ingestion	In mild cases may experience: • increased salivation, perspiration/sweating, and watery eyes/tearing (lacrimation) In severe cases may experience: • abdominal pain, severe nausea, diarrhea, blurred vision, laboured

			breathing, and ingestion of large doses may cause cardiac/respiratory failure
Ibotenic Acid and Muscimol	*A. muscaria (Fly Agaric), A. pantherina (Panthercap), A. gemmate*	Usually within 1 to 2 hours after ingestion	May experience: • nausea, vomiting, diarrhea, colour hallucinations, slow pulse, hypotension, irritability, lack of coordination, anxiety, hysteria, convulsions, fever and seizures (in children), abdominal discomfort, drowsiness, dizziness, hyperactivity, excitability, and coma
Psilocybin and Psilocin	*P. cubensis (Golden tops),P. mexicana*, *P. cyanescens*, *P. semilanceata* (Liberty cap), *C. cyanopus*	Usually within 20 minutes after ingestion	May experience: • anxiety, tension, visual effects (e.g., blurring), euphoria, increased colour perception (with eyes closed), headache, and fatigue

- **Gastrointestinal Irritants**

Some mushrooms (such as Jack O'Lantern and Naked Brimcap) contain toxins that can irritate the gastrointestinal tract (see Table 5).

Table 5. Mushrooms and gastrointestinal irritants

Toxins	Mushrooms	Symptoms in humans
Gastrointestinal Irritants	*Chlorophyllum molybditis* (Green Gill), *Entoloma lividum* (Gray Pink gill), *Tricholoma pardinum* (Tigertop), *Omphalotus illudens* (Jack O'Lantern), *Paxillus involutus* (Naked Brimcap), *Russula emetica* (Sickener), *Verpa bohemica* (Early False Morel) confused with *Morchella esculenta* (True Morel), *Agaricus arvensis, A. xanthodermus* (Horse Mushroom), and *Boletus piperatus, B. calopus, B. santanas* (Pepper Bolete)	May experience: • nausea, vomiting, diarrhea, and abdominal pain

- **Coprine or Disulfiram-like Toxins**

Coprine is an amino acid produced by some mushroom species such as Coprine atramentarius (Inky-cap mushroom) and Clitocybe clavipes (Fatfooted Clitocybe). Coprine is converted in the body to cyclopropanone hydrate, which interferes with the breakdown of alcohol during the consumption of alcoholic beverages. It is important to note that no illness (see Table 6) will occur if no alcohol is consumed within 72 hours of eating mushrooms that contain coprine or disulfiram-like toxins.

Table 6. Mushrooms and coprine or disulfiram-like toxins

Toxins	Mushrooms	Symptoms in humans
Coprine or Disulfiram-like Toxins	*Coprine atramentarius* (Inky-capmushroom), *Clitocybe clavipes* (Fat-footed Clitocybe)	If alcohol is consumed within 72 hrs of ingesting the toxin, may experience: • headache, nausea, vomiting, flushing and cardiovascular disturbances, dilation of the pupils (mydriasis), abnormal skin sensations (paraesthesia), abnormal rapid heartbeat (tachycardia), sweating, and nausea

Self-Assessment Exercises 2

1. What are Mycotoxins?
2. List the types of mycotoxins you know
3. List the types of mushroom toxins you know

1.5 Summary

Exposure to natural toxins needs to be kept as low as possible to protect people. Natural toxins not only pose a risk to both human and animal health, but also impact food security and nutrition by reducing people's access to healthy food. WHO encourages national authorities to monitor and ensure that levels of the most relevant natural toxins in their food supply are as low as possible and comply with both national and international maximum levels, conditions and legislation.

In this unit we examined naturally occurring toxins: microbial toxins; algae and fungal toxins, their effects on humans, the various symptoms and reaction time, and the possible preventive measures, to equip you with adequate knowledge against the toxins for a healthy life.

1.6 References/Further Reading

Food Safety for First Nations People of Canada: A Manual for Healthy Practices retrieved from https://dhss.alaska.gov/dph/Epi/eph/Documents/FNIHBFFoodManual.pdf

1.7 Possible Answers to Self-Assessment Exercise

Self-Assessment Exercises 1

3) The most common algal toxins are saxitoxins, brevetoxins, dinophysistoxins, domoic acid and ciguatoxins.
4) Shellfish and finfish contaminated with these toxins can be potentially harmful to human health, causing a variety of foodborne illnesses such as Paralytic Shellfish Poisoning (PSP), Neurotoxic Shellfish Poisoning (NSP), Diarrheic Shellfish Poisoning (DSP), Amnesic Shellfish Poisoning (ASP) and Ciguatera Fish Poisoning (CFP)

Self-Assessment Exercises 2

- Mycotoxins are toxic secondary metabolites produced by fungi found in food (e.g., grains, nut crops, celery, grape juice, and apple juice). The consumption of foods contaminated with mycotoxins can cause mycotoxin poisoning, referred to as mycotoxicosis.
- The most common types of mycotoxins are aflatoxin, ochratoxin, trichothecenes, patulin, fumonisin, zearalenone and ergot alkaloids.
- Mushroom poisoning can be caused by four types of toxins: protoplasmic toxins, neurotoxins, gastrointestinal irritants, and coprine or disulfiram-like toxins.

UNIT 2 NATURALLY OCCURRING TOXINS: BACTERIAL AND PLANT TOXINS

CONTENTS

2.1 Introduction

In the previous unit we examined naturally occurring toxins; microbial toxins: algae and fungal toxins.

In this unit we shall continue with naturally occurring toxins; microbial specifically bacterial toxins

2.2 Learning Outcomes

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

- discuss the bacterial toxins and the associated foodborne intoxication
- discuss the plant toxins and the associated plants/fruits/vegetables/nuts

2.3 Bacterial Toxins

There are two main types of bacterial toxins: endotoxins and exotoxins. Both can cause foodborne intoxication if ingested (See Table 1 for a list of the most common foodborne intoxications related to bacterial toxins). Bacterial toxins can cause a number of foodborne illnesses, such as botulism, and Staphylococcus-related illnesses.

2.3.1 Endotoxins

Endotoxins are toxic substances bound within the cell walls of gram-negative bacteria, which are secreted when the cells rupture or die. Endotoxins are produced by different types of bacteria, such as Salmonella, Listeria monocytogenes, Vibrio cholera and Shigella. These toxins are heat-resistant; they are not destroyed by cooking. There are different types of endotoxins, such as scombrotoxin.

- **Scombroid Poisoning**

Scombroid poisoning is produced from the conversion of the amino acid, histidine, to histamine by some bacteria in fish. Histamine-forming bacteria are found in the gills and gut of contaminated fish.

The fish particularly affected are the Scombridae and Scomberesocidae families (e.g., tuna and mackerel), the Clupeidae (herring, sardines) and the Coryphaenidae (mahi-mahi/dolphinfish/dorado). Bacteria that transform histidine into histamine (mainly in oily fish) can be found in fish that is inadequately preserved or chilled. To slow the growth of bacteria that can cause scombroid poisoning, fish should be kept at 0°C/32°F or below. Scombrotoxin cannot be destroyed by cooking, canning or freezing. To avoid cross contamination, food handlers should wash their hands before and after handling fish.

2.3.2 Exotoxins

Exotoxins, or extracellular toxins, are toxic substances excreted by living gram-positive and gram-negative bacteria during their growth. Exotoxins are excreted by different types of bacteria, such as Clostridium tetani, Corynebacterium diphtheriae, and Clostridium botulinum. Most exotoxins can be destroyed by heat. Exotoxins are characterized by their mode of action on targeted tissues and organ systems.

- **Enterotoxins**

Enterotoxins are exotoxins that are harmful to parts of the lower intestines. In humans, they destroy the cells of the intestinal lumen and surrounding tissue. *Escherichia coli, Clostridium perfringens, Vibrio cholerae, Staphylococcus aureus, Shigella dysenteriae*, and *Yersinia enterocolitica* are examples of bacteria that produce enterotoxins. Unlike most exotoxins, some enterotoxins are heat-stable hence not easily destroyed by cooking.

- **Neurotoxins**

Neurotoxins are exotoxins that affect the tissues of the nervous system when ingested. They are produced by bacteria in certain plants, mushrooms and animals, such as snakes, finfish and shellfish (e.g., pufferfish, mussels). Examples of neurotoxins are C. botulinum toxin, ciguatoxin, holocyclotoxin and tetrodotoxin.

Table 1. Bacterial toxins and associated foodborne intoxication

Endotoxin

TOXINS	Bacteria	Illness	Symptoms found in animals	Symptoms found in humans	Reaction time in humans	Associated foods/animals
Scombrotoxin	Histamine forming bacteria	Scombroid poisoning		May experience: • rash, flushed skin, facial	Usually within minutes to several hours after eating	Tuna, mackerel, bonito, herring, sardines, mahimahi, and otters

				swelling, nausea, vomiting, diarrhea, headache, dizziness, a peppery taste in the mouth, burning throat, stomach pain, itchy skin, tingling, and palpitations	spoiled fish	
Preventive Measures	• Obtain fish from a reliable supplier • Chill fish rapidly	• Refrigerate or put on ice or in the freezer as soon as possible after catching or buying fish		• Food handlers with lesions on hands should ensure that their hands are properly covered (wear gloves to avoid contamination of food)		• Eviscerate and remove the gills to prevent spoilage • Do not eat decomposed fish

Exotoxin

Toxins	Bacteria	Illness	Symptoms found in animals	Symptoms found in humans	Reaction time in humans	Associated foods/animals

Enterotoxins	*Bacillus cereus*	*Bacillus cereus*		May experience: • severe nausea, vomiting, abdominal cramps, and diarrhe	Nausea and vomiting occur usually within 1-6 hours (average4 hours) after ingestion Abdominal cramps and diarrhea occur usually within 6-24 hours (average17 hours) after ingestion	Food left at room temperature, such as cooked vegetables (e.g., alfalfa sprouts, cress sprouts, and cucumbers),meat, boiled or fried rice, vanilla sauce, custards, soups, ice cream, herbs, spices, sandwiches, and cold cuts
Preventive Measures	• Food handlers with lesions on hands should ensure that their hands are properly covered(wear gloves to avoid contamination of food)	• Keep cooked rice hot,above60ºC/ 140ºF,until served • Cool rice quickly(in shallow pans) to a temperature below 4ºC/40ºF in less than 4 hours and reheat to a temperatureof74ºC/165ºF within 2 hours		• Cook and hold foods at recommended temperatures • Serve hot foods hot and cold foods cold		• Do not keep cooked food at room temperature for longer than 2 hours

Enterotoxins	*Clostridium perfringens*	Clostridium perfringens		May experience: • Nausea and abdominal cramps	Usually within 8 to 24 hours after ingestion	High protein, starchy foods (e.g., meat, poultry, sauces, and gravies) and other foods held at warm temperatures before serving, food left at room temperature or on steam tables for too long ,meats, meat products, and gravy
Preventive Measures	• Do not keep cooked food at room temperature for longer than two hours • Do not cook too much food in advance	• Divide left overs into smaller portions in shallow containers for faster cooling		• Freeze or discard leftovers after four days • Keep hot foods above 60ºC/140ºF until served		• Reheat leftovers to 74°C/165°F

Enterotoxins	*Staphylococcusaureus*	*Staphylococca*		May experience: • Nausea, stomach cramps, diarrhea, and vomiting	Usually within 1 to 6 hours after ingestion	Salted meat, (e.g., smoked ham, sliced meat),dairy products (e.g., milk, cheese), puddings, some pastries, sandwiches, poultry, egg products, fish, cooked pasta, and fruits and vegetables (alfalfa sprouts, carrots, lettuce, parsley, scallions/green onions)
Preventive Measures	• Do not keep cooked food at room temperature for longer than two hours • Do not cook	• Divide leftovers into smaller portions in shallow containers for faster cooling		• Freeze or discard leftovers after four days • Keep hot foods above 60ºC/140ºF until served		• Reheat leftovers to 74°C/165°F

	too much food in advance					
Exotoxins	*Bacillus anthracis*	Anthrax	Infected animals may appear distressed, weak, have difficulty breathing, stop eating and drinking, develop swelling under the jaw or lower abdomen, and have normal or elevated temperature The infected carcass may bloat and decompose quickly, may also leak	The disease can manifest itself in 3forms: 1)Cutaneous: a small painless bump on the skin which becomes a blister and then an ulcer with a black centre 2)Gastrointestinal: fever, loss of appetite, vomiting, and diarrhea 3)Pulmonary:	Usually within 1to7 days after exposure/ ingestion	Wood bison, white tailed deer, elk, caribou, moose, bobcat, cougar, raccoon, and mink

			bloody discharge from the mouth, nose, and anus	Resembles the flu and includes fever, sore throat and general feeling of unwellness, shortness of breath, chest pain, and difficulty breathing		
Preventive Measures	• Do not eat infected animals	• Do not handle carcasses of infected anima				
Neurotoxins	*Clostridium botulinum*	Botulism		May experience: • nausea, vomiting, fatigue, weakness, dizziness, headache, blurred vision, dry	Usually within 12 to 36 hours after ingestion	Improperly home-prepared, preserved and canned game: fish, land and marine mammals (e.g., salmon, caribou,

				throat and nose, difficulty swallowing and speaking, diarrhea, constipation, and abdominal swelling. In severe cases ,may experience: •respiratory failure, paralysis, and death		beaver, seal, whale, walrus meat), fermented beaver tail, seal flippers, fermented salmon roe and head, fermented sea mammal meat in oil (seal meat and walrus), dried seal meat, aged seal oil, improperly stored game, and improperly home-smoked salmon Improperly canned and stored foods (e.g., corn, green beans, baked

						potatoes, and honey)
Preventive Measures	• Cook foods to recommended temperatures • Do not eat foods from damaged (dented, leaking or bulging) cans • Do not use or eat from cans that have an unpleasant odour when opened • Refrigerate all home-made foods that are preserved in oil, and use within ten days • Do not feed honey to children less than one year of age • Date and label	• Do not store beluga, seal, narwhal or walrus at warm temperatures or in a container that does not allow proper air circulation • Age narwhal, seal, beluga and walrus in very cool places • Use safe methods to prepare traditional foods: - Follow traditional methods (e.g., grass-lined hole in the ground) or other methods that allow air to circulate to ferment foods - Ferment foods in a cool (below 3°C/37°F), shaded, shallow pit in the ground lined with wood, animal skins or leaves and covered with moss or leave		- Do not use plastic or glass containers with tight fitting lids or buckets to ferment food(these containers do not allow air to circulate) - Do not ferment foods above ground or indoors on the counter at room temperature – Consider boiling fermented food for at least ten minutes to destroy the botulism toxin that may be present before you eat it		Canning • Use a pressure canner to can low acid foods at home • Preserve and can foods properly, following recommended procedures • Cook canned foods at 80ºC/176ºF for at least 10minutes to destroy the toxins that may be present • Do not re-use the lids of home canned foods as they may not seal

	all preserves and home-canned foods	properly after being used previously When in doubt about the safety of a food, throw it out

Self-Assessment Exercises 1

1. What is bacterial toxins?
2. What are the 2 main types of bacterial toxins?

2.4 Plant Toxins

Fruits, vegetables and other plant foods (including sprouts, leaves, seaweeds, roots, bulbs, tubers and inner bark tissues) are an important source of vitamins A and C, calcium, iron and fibre. Some food plants produce small amounts of toxins, referred to as phytotoxins (such as alkaloids and glycosides), in order to protect themselves against insects, diseases and plant-browsing animals.

Some plants are poisonous to humans at different stages of maturity. A plant is poisonous if it can make people ill after touching, tasting or swallowing its parts. Some of the most common phytotoxins found in plants are: cyanogenic glycosides, glycoalkaloids, lectins, oxalates and oxalic acid, and cucurbitacin (see Table 12).

- **Cyanogenic Glycosides**

Cyanogenic glycosides are naturally occurring toxins found in some wild plants, fruits and vegetables such as:

- bracken fiddleheads (with high concentration found in the rhizomes and fiddleheads),
- wild cherries such as choke, black, bitter and pin (found in the leaves, twigs, shoots, bark, and seed kernels,
- berries such as serviceberry, and Saskatoon berries (found in the leaves and twigs),
- elderberries (found in the roots, stems, bark and leaves including the flower and unripe fruit).

These toxins can convert to hydrogen cyanide when ingested and are the primary causes of cyanide poisoning from food. The lethal dose of cyanide for all age groups of the population ranges from 0.5 to 3.0 mg per kilogram of body weight. Adequate boiling significantly reduces the amount of cyanide present in glycoside-containing plants. These plants should therefore never be eaten raw and they should always be well-cooked.

- **Glycoalkaloids**

Glycoalkaloids are naturally occurring toxins, such as solanine, tomatine and charconine, found in some fruits and vegetables, such as eggplants, peppers, tomatoes and potatoes. Washing, soaking and cooking cannot destroy these particular toxins as they are heat resistant. The highest concentration of solanine and charconine in potatoes is found in the skin, eyes and sprouts of the tubers. Improper storage, light exposure, physical damage (e.g., cuts and bruises), and rotting (caused by bacteria or fungi) may facilitate the rapid production of these toxins. Sprouted, greened or damaged potatoes should not be consumed.

To reduce exposure to glycoalkaloids in potatoes:

- Store in a dark, cool and dry place – away from sun or artificial light,
- Cut away any parts that show damage (cuts and bruises), rotting and sprouting,
- Peel the skin to reduce the level of glycoalkaloids,
- Do not eat potato sprouts, flowers, and areas around the eyes, and
- Do not eat potatoes that taste bitter or cause a burning sensation in the mouth.

To reduce exposure to glycoalkaloid in tomatoes:

- Eat green tomatoes and its products in moderation (e.g., green tomato relish, fried green tomatoes), and
- Do not eat the green parts of tomato plants.

- **Lectin**

Lectin is a naturally occurring toxin found in raw kidney beans (especially the red variety) and green beans. To destroy this toxin, soak kidney beans in water for at least 5 to 12 hours and then cook in fresh water at high temperatures (60ºC/140 ºF) for at least 10 to 30 minutes evenly. Cooking these beans at a low temperature or with uneven heat transfer does not destroy the toxin and can cause the cooked beans to be more toxic than the raw ones

- **Oxalates and Oxalic Acid**

Oxalates are compounds ("salts") that form when oxalic acid is combined with metal ions such as calcium, magnesium, or potassium. Oxalic acid is a naturally produced metabolic by-product found in various plants in low concentrations. Foods that typically contain higher amounts of oxalates or oxalic acid are spinach, sorrel, beets chard, skunk cabbage, and rhubarb (highest concentrations are found in the leaves) and cannot be destroyed by heat.

Cucurbitacin

Cucurbitacin is a poison released in small amounts by the Cucurbitacean family, including squash, pumpkins, zucchini, cucumbers, and melons, as a defence against insects. Cucurbitacin is commonly found in wild zucchinis. This toxin releases a strong and unpleasant smell and gives a bitter taste to food.

Table 2. Plant toxins

TOXINS	Associated plants/fruits/vegetables/nuts	Symptoms in humans
Cyanogenic glycosides	Apple and pear seeds (in low levels),mangoes, bitter almonds, cassava roots (manioc), wild cherries, the inner kernel (pit) of apricots and peaches, lima beans, chickpeas, and cashew nuts	May experience: • rapid pulse and breathing, drop in blood pressure, dizziness, headache, stomach pains, vomiting, diarrhea, mental confusion, twitching, and convulsions

Glycoalkaloids	Roots, seeds, leaves, bark and stems, poppy, lupine, coffee, tea and cocoa, eggplant, tomatoes, and potatoes	May experience: • bitter or burning sensation in mouth, excess salivation, dilation or constriction of the pupils, vomiting, abdominal pain, diarrhea, lack of coordination, convulsions, and coma
Lectin	Kidney beans and green beans	May experience: • stomach ache, diarrhea, and vomiting
Oxalates and oxalic acid	Spinach, rhubarb, sorrel, and beets	May experience: • muscle twitching, cramps, decreased breathing, heart palpitations, vomiting, abdominal pain, headache, convulsions, and coma • an increase in the risk of kidney stone formation
Cucurbitacin	Squash, pumpkins, zucchini, cucumbers, and melons	May experience: • vomiting, stomach cramps, and diarrhea

Self-Assessment Exercises 2

1. What does Cyanogenic glycosides do to humans?
2. Where is the lectin toxin found and how can it be destroyed?

2.5 Summary

Bacterial toxins are proteins capable of achieving multiple remarkable tasks. They function as autonomous molecular devices, targeting specific cells in an organism, punching holes in their membranes, or modifying intracellular components.

Some plants are poisonous to humans at different stages of maturity. A plant is poisonous if it can make people ill after touching, tasting or swallowing its parts

In this we continued with naturally occurring toxins; microbial specifically bacterial toxins: endotoxins, exotoxins and plant toxins

2.6 References/Further Reading

Food Safety for First Nations People of Canada: A Manual for Healthy Practices retrieved from https://dhss.alaska.gov/dph/Epi/eph/Documents/FNIHBFFoodManual.pdf

2.7 Possible Answers to Self-Assessment Exercise

Self-Assessment Exercises 1

1. Bacterial toxins are virulence factors that manipulate host cell functions and take over the control of vital processes of living organisms to favor microbial infection. Some toxins directly target innate immune cells, thereby annihilating a major branch of the host immune response.
2. Bacterial toxins are classified into two major types: Endotoxins and exotoxins. Endotoxins are specifically referred to as cell-associated toxins—non-protein lipopolysaccharides associated with the cell wall of Gram negative bacteria. They act at, or near, the bacterial growth site. Exotoxins are proteins secreted by bacteria and act at a site farther away from the secretion site. Enterotoxins, neurotoxins, cytotoxins, lysins (e.g., hemolysin), gangrene-producing toxins, etc., are some examples of bacterial endotoxins, the names also indicating the site of action of the toxin.

Self-Assessment Exercises 2

1. Exposure to cyanide from unintentional or intentional consumption of cyanogenic glycosides may lead to acute intoxications, characterized by the following symptoms: rapid pulse and breathing, drop in blood pressure, dizziness, headache, stomach pains, vomiting, diarrhea, mental confusion, twitching, and convulsions
2. Lectin is a naturally occurring toxin found in raw kidney beans (especially the red variety) and green beans. To destroy this toxin, soak kidney beans in water for at least 5 to 12 hours and then cook in fresh water at high temperatures (60ºC/140 ºF) for at least 10 to 30 minutes evenly. Cooking these beans at a low temperature or with uneven heat transfer does not destroy the toxin and can cause the cooked beans to be more toxic than the raw ones

UNIT 3 NATURALLY OCCURING AND ENVIRONMENTAL CHEMICAL CONTAMINANTS

CONTENTS

3.1 Introduction

Environmental contaminants are chemicals that accidentally or deliberately enter the environment, often, but not always, as a result of human activities.

In this unit we shall focus on naturally occurring and environmental chemical contaminants; environmental contaminants, factors that determine the harmfulness of chemicals in the body, common contaminants found in food and heavy metals.

3.2 Learning Outcomes

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

- discuss environmental contaminants
- discuss the factors that determine the harmfulness of chemicals in the body
- analyse the common contaminants found in foods
- evaluate some heavy metals and their effects in humans

- **Preamble**

Synthetic and natural chemicals (e.g., metals) can be released as a result of industrial processes. When released in the environment, these contaminants may enter the food chain, where they pose potential health risks to living things.

3.3 Environmental Contaminants

Environmental contaminants can be found naturally, or are released into the environment accidently or deliberately as a result of human activities. Some contaminants have been manufactured for industrial use and because they are very stable, they do not break down easily. Other environmental contaminants are naturally-occurring chemicals, but industrial activity may increase their mobility allowing them to enter the food chain at higher levels than would otherwise occur.

Environmental contaminants that are present in the air, water or soil may be taken up by plants, wildlife and fish, and a wide variety have been detected in foods. These contaminants range from metals and "ionic" species like perchlorate, to organic (e.g., carbon-based) substances, including "persistent organic pollutants" (POPs) – named for their ability to remain in the environment for prolonged periods without breaking down. Some POPs such as Polychlorinated biphenyls (PCBs) that have been banned for industrial or agricultural use in various countries for many years still remain in the food chain. Other POPs, such as brominated flame retardants, have been more recently identified, and have been found in the environment and the food chain.

3.3.1 Factors that determine the harmfulness of Chemicals in the body

The effect of the chemical on the body depends on the following factors:-

1. Route of exposure (e.g., skin contact/dermal absorption, inhalation, or ingestion)

2. Amount entering the body

3. Characteristics of the chemical (e.g., toxicity, rate of removal from the body)

4. Biological variation of humans.

- **Routes of exposure**

Contaminants may enter the aquatic food chain through water bodies; plants, through contaminated soil; and deposition onto food plants through contaminants in the air.

Contaminants that are absorbed through ingestion enter the blood stream and are carried to different parts of the body. They are then stored either in the fat or bone, or metabolised by the liver and excreted through urine, lungs, sweat, semen, milk, saliva and bile. Infants can be exposed to contaminants in breast milk, though it is important to keep in mind that the benefits of breastfeeding outweigh the health risks posed by the low levels of contaminants that have been detected in breast milk.

- **Amount entering the body**

The amount and frequency of any chemical entering the body is very important as it is the amount (or dose) that determines whether or not the chemical will pose a concern to the health of a person. Exposures can be either short-term or long-term: - Short-term exposure to a contaminant is often associated with higher concentrations of contaminants. - Long-term exposure to a contaminant is more often associated with lower concentrations of contaminants.

- **Type and toxicity**

Toxicity is a measure of the poisoning strength of a contaminant. For contaminants that are not very toxic, large amounts are needed to cause poisoning, and for those that are very toxic, only small amounts are needed to cause poisoning.

- **Rate of removal**

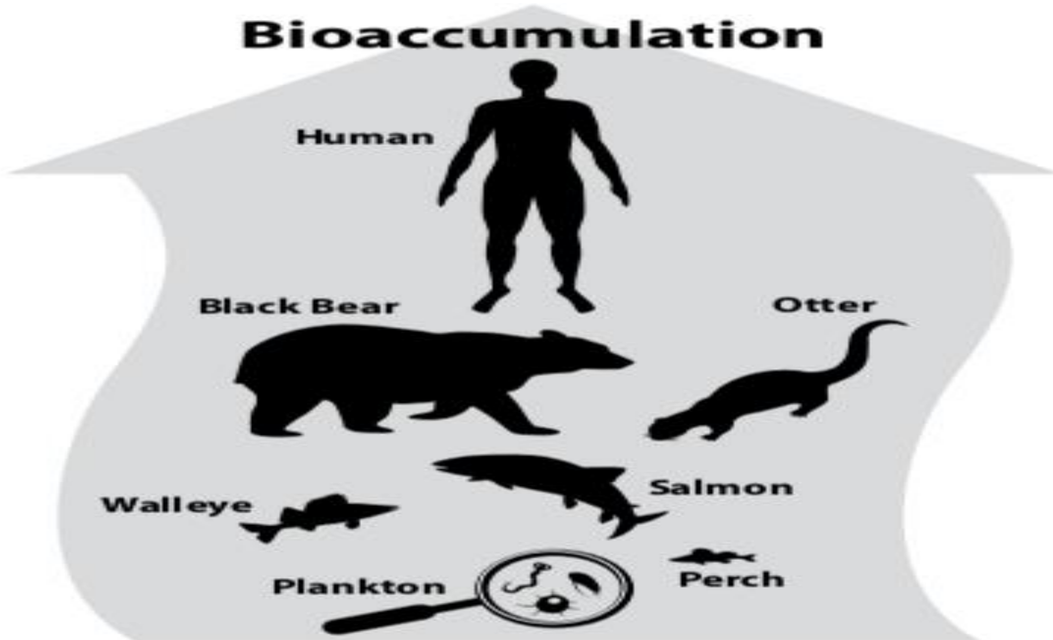
Many chemicals entering the body may be excreted unchanged, while others are broken down by the human body. Eventually, most contaminants are removed from the body as waste in the faeces, urine, and sweat, or as exhaled breath. The health risks to people are reduced if the body is able to break down the contaminants into a less toxic product or rapidly remove them from the body.

- **Biological variation**

Biological variation refers to the different characteristics (e.g., age and gender) of an individual that may make him/her more susceptible to poisoning from contaminants. Young children, the elderly, pregnant or lactating women, those with a weakened immune systems and individuals with poor nutritional status may be more susceptible to the toxic effects of chemical contaminants.

Bioaccumulation is the concentration of a toxic chemical that gradually increases in the living tissues of plants, animals or people as they continue to drink contaminated water, or eat contaminated food.

Biomagnification is the result of the accumulation of a chemical in an organism at higher levels than are found in its food supply. It occurs when a chemical becomes more concentrated as it moves up through the food chain. For example, animals that eat other animals and plants consume all the contaminants that their food sources were exposed to. As a result, the animals at the very top of the food chain are exposed to the highest levels of contaminants. Plants, wildlife and humans absorb heavy metals from various food sources. In some wildlife (e.g., caribou, seal, fish), the levels of metals are often higher in the organs than in the muscle/ meat.



Self-Assessment Exercises 1

1. Enumerate the factors that determine the harmfulness of Chemicals in the body?
2. What is Biomagnification?

3.4 Common Contaminants found in Foods

The most common contaminants that can be found in foods are:

- Heavy metals • Cadmium (Cd), Lead (Pb), Mercury (Hg) and Arsenic (Ar) • Persistent Organic Pollutants (POPs)
- Pesticides: aldrin, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, Dichloro-DiphenylTrichloroethane (DDT), chlordane and toxaphene
- Industrial chemicals: Polychlorinated biphenyls (PCBs),
- By-products: polychlorinated dibenzo-p-dioxins (PCDD) (e.g., dioxins) and polychlorinated dibenzofurans (PCDF) ("furans") • Polybrominated diphenyl ethers (PBDEs)

- Perfluorinated chemicals • Perfluorooctane sulfonic acid (PFOS) • Perfluorooctanoic acid (PFOA) • Polycyclic aromatic hydrocarbons (PAHs)
- Radionuclides • Polonium, Radium, Cesium, Strontium, and Uranium

3.4.1 Heavy metals

Heavy metals (e.g., cadmium, lead, mercury and arsenic) are naturally occurring. They can also enter the environment as a result of anthropogenic activities. For example, naturally occurring chemicals can be the result of the weathering of rocks and soil which can release metals into rivers and lakes. Human activities such as mining, clear cutting, industrial processes, and burning of fossil fuels, garbage, and forests, also release heavy metals into the environment. Heavy metals are a cause for concern because they do not break down over time and tend to bioaccumulate in the body. The rate at which a chemical is absorbed (bioavailability) is an important factor in toxicity. While some metals (at low levels) are considered essential nutrients for humans (e.g., iron and zinc), others such as cadmium, mercury and lead, are not needed by the body and can be harmful (see Table 15 for heavy metals and their effects).

3.4.1.1 Cadmium

Cadmium is a naturally occurring element found in the environment. It appears as a soft, silver-white, heavy metal and enters the soil, water, and air from mining, industry, and burning coal and household wastes. Cadmium has many uses, such as in batteries, pigments, metal coatings, and plastics.

- **Cadmium in Humans**

Human exposure to cadmium occurs through the consumption of contaminated foods e.g., milk, meat, fish, fruit, wheat, rice and potatoes. Cadmium levels in humans accumulate with age, with highest concentrations found in the kidney and liver.

- **Cadmium and Wildlife**

The highest cadmium levels (100-1000 μg/kg) are found in the internal organs (kidney and liver) of mammals and in certain species of mussels, scallops and oysters. Cadmium does not break down easily in animals and it tends to increase with age. Cadmium levels bioaccumulate in marine mammals, making marine mammals more adversely affected by cadmium exposure than birds and land mammals.

3.4.1.2 Lead

Lead is a persistent heavy metal that occurs naturally in the environment and is also released as a result of human activities. When released in the air, lead travels long distances in the environment. Though lead itself does not break down, its compounds such as lead acetate, lead chloride, and lead chromate, are altered by exposure to sunlight, air and water. Mobility and bioavailability of lead are influenced by pH, soil texture (clay content) and organic content.

- **Lead in Humans**

Exposure to lead in humans is from the consumption of lead-contaminated wildlife (such as moose, deer, and waterfowl) that have been shot by lead shots/ pellets (Verbrugge et al, 2008). The effects of lead in humans are the same, whether it enters the body through breathing or ingestion. Lead can affect almost every organ and system in the body.

Once lead is absorbed, it circulates in the bloodstream where it gradually accumulates in soft tissue such as the liver, kidneys, pancreas and lungs, with a high proportion transferred to the bone, where it accumulates over time and remains for long periods. The estimated time for the body to excrete half the accumulated lead is about 25 years.

- **Lead and Wildlife**

Lead poses a threat to wildlife, especially waterfowl and birds of prey. In wild mammals, lead poisoning is the result of the consumption of lead contaminated prey.

3.4.1.3 Mercury

Mercury is a heavy metal that does not break down in the environment and hence, bioaccumulates. Mercury is released into the atmosphere as a result of human activities, such as combustion and industrial activities. Once in the atmosphere, it is widely dispersed and can circulate for many years. The long atmospheric lifetime of its gaseous form makes the emission, transport and deposition of mercury a global issue.

The concern over mercury in the environment arises from the toxic forms in which it can occur. Once released, mercury enters the air, water and soil and continues to move over long periods of time, depending on its chemical form.

- **Mercury exists in three forms:**

   1. Elemental (metallic) mercury is the pure form of mercury. It is a heavy, shiny, silver-white volatile liquid that releases a colourless and odourless toxic vapour at room temperature. It is the primary form of mercury released into the air by natural processes, such as volcanic activity.

2. Inorganic mercury enters the air, water, or soil from the weathering of rocks that contain mercury or from mining ore deposits, burning coal and waste, and from manufacturing plants. It is formed when elemental mercury combines with other elements such as sulphur, chlorine or oxygen to create compounds known as mercury salts.
3. Organic mercury is formed when elemental mercury combines with carbon. Microorganisms in the environment can convert inorganic mercury to the organic form of mercury, also known as methylmercury. Methylmercury is a highly toxic organic compound of mercury, and is more toxic than elemental mercury.

- **Mercury in Humans**

In humans, the main source of mercury exposure is from the consumption of fish – present in the form of methylmercury. A wide range of adverse health effects has been observed in humans following methylmercury exposure, and the severity depends on the magnitude of the dose and the duration of exposure. The central and peripheral nervous systems are generally considered to be the target organs of organic mercury-induced toxicity in humans.

- **Mercury and Wildlife**

Mercury levels in wildlife depend on the body of water, the species, age and size of the animal. Younger and smaller animals tend to have lower concentrations of mercury than older and larger ones within the same water body.

3.4.1.4 Arsenic

Arsenic is a naturally occurring element widely distributed in the earth's crust. Arsenic is classified as a metalloid; it exhibits properties of both a metal and a non-metal. Arsenic exists in different forms and can be classified into two groups: organic and inorganic. Inorganic arsenic is considered to be the most toxic to human health. Arsenic can be found in both surface water and ground water sources; levels are generally higher in ground water.

Foods that have been found to contain very low levels of arsenic include meat and poultry, milk and dairy products, bakery goods and cereals, vegetables, and fruits and fruit juices. These trace levels of arsenic reflect normal accumulation found in the environment. While both organic and inorganic arsenic can be found in food, the levels of each depend on the type of food; inorganic arsenic is not usually found at high levels.

- **Arsenic in Humans**

Exposure to arsenic in humans is from the consumption of contaminated food (particularly meat, fish and shellfish) and drinking water.

Long-term exposure to high levels of inorganic arsenic may contribute to the risk of cancer and can affect the gastrointestinal tract, kidneys, liver, lungs, and skin. Skin, bone, and muscle represent the major storage organs. Short term exposure to high levels of inorganic arsenic can also cause various health effects including skin effects, nausea, diarrhea, vomiting and numbness in hands and feet.

- **Arsenic and Wildlife**

Arsenic concentrations in plants and animals are usually low, but are elevated in marine biota; higher levels of organic arsenic are generally found in fish, shellfish and seaweed. The organic form of arsenic (arsenobetaine) poses little risk in fish and shellfish, and therefore a low risk to humans who consume them. While arsenic is bioconcentrated by organisms, it does not biomagnified in the food chain.

Table 1. Heavy metals and their effects

HEAVY METALS	Source	Sources of exposure in animals	Sources of exposure in humans	Effects in humans	Reducing Exposure *For more information on consumption, consult your EHO, or your local, provincial, territorial governments*
Cadmium	Burning of coal or oil, vehicle exhaust, cigarette smoke, metal processing industries, mining, waste hauling, waste disposal activities, soil, surface water (as dust), volcanoes, and weathering of	Plants (e.g., lichens, willows) grown in contaminated soil or water	Foods grown in contaminated soils (e.g., mushrooms),organ meats from contaminated animals, (e.g., caribou, and moose), shellfish and plants from	Acute exposure may cause: • Irritation of the stomach, vomiting, and diarrhea Chronic exposure: • Maternal exposure to cadmium is associated with an increase in	Eat a balanced diet (this reduces the amount of cadmium absorbed by the body). Refer to Canada's Food Guide for First Nations, Inuit and Métis. http://www.hc-sc.gc.ca/fn-an/pubs/fnim-pnim/index-eng.php • Avoid meat or organs that may have been shot by lead

	rocks		contaminated waters (e.g., mussels, oysters, and seaweed), and contaminated drinking water	spontaneous abortions and low birth weight babies	• Follow consumption guidelines for oysters in your area to minimize the intake of cadmium • Do not harvest fish or shellfish from closed harvest areas
Lead	Burning of fossil fuels, mining, thermal power plants, vehicle exhaust, old paint work, production of batteries, ammunition (e.g., lead shots used for hunting), fishing sinkers, tackle and other related fragments, solder and lead pipes, devices used to shield x-rays, some children's toys, crayons, chalk, air near emission sources, house	Gravel contaminated with lead pellets, wounded or dead prey containing lead shot, and lead bullets or fragments	Contaminated foods such as wild birds (e.g., duck, swan, and geese), wild game, and crops grown in contaminated soil Contaminated water and the use of lead-glazed ceramics to cook	Acute exposure may cause: • Convulsions and memory loss Chronic exposure may cause: • muscle weakness, loss of appetite, abdominal pain, constipation, sleeplessness, irritability, headache, impaired mental function, impaired visual and motor	• Avoid the meat or organs that may have been shot by lead • Do not put food or beverages in any leaded crystal containers (particularly acidic foods such as fruit juice) • Avoid drinking from leaded crystal (HC, 2008a,f) • For more information on lead, consult: http://www.hc-sc.gc.ca/ewh-semt/contaminants/lead-plomb/asked_questions-questions_posees-eng.php

	dust, soil, and paint flakes in old house			performance, brain and kidney damage, damage to the nervous and reproductive systems, and weakness in fingers, wrists, or ankles In men, high exposure levels may: • damage the organs responsible for sperm production. In pregnant women may cause: • miscarriages and stillbirth In young children may	

				cause: • decreased IQ, developmental delays, hearing problems, and behavioural disturbances	
Mercury – Elemental (metallic)	Industrial processes, various commercial products (e.g., batteries, lamps, thermometers), dentistry(e.g., amalgam fillings), the pharmaceutical industry, sphygmomanometers (devices used to test blood pressure), electrical switches, lakes, streams and oceans, goldmine sites, spills, incinerators, and		Amalgam fillings and inhalation of mercury vapour	Acute exposure may cause: respiratory problems (such as, cough, sore throat, and shortness of breath), gastrointestinal problems (e.g., metallic taste, nausea, vomiting, diarrhea, and abdominal pain) as well as headache, weakness, and visual disturbances	• Follow Health Canada's consumption advice that has been issued for certain types of commercially-available predatory fish (see: http://www.hc-sc.gc.ca/ fn-an/securit/chem-chim/environ/ mercur/cons-adv-etud-eng.php) • Follow Federal Provincial Territorial (F/P/T) advice on sport fish consumption • Eat a variety of fish and shellfish that contain low levels of mercury and high concentrations

	fossil fuels				ofomega-3fattyacids
Mercury – Inorganic	Mining of ore, coal burning, and waste incineration		Breathing vapours from spills, incinerators, and mercury containing fuels	Chronic exposure may cause: renal damage Acute exposure may cause: • neurological damage, damage to the mouth, respiratory tract and lungs, and respiratory failure which can cause death	(e.g., anchovy, capelin, char, hake, herring, Atlantic mackerel, mullet, Pollock (Boston bluefish), salmon, smelt, rainbow trout, lake whitefish, blue crab, shrimp, clam, mussel and oyster, (refer toChapter6on fish), limit consumption of predatory birds and fish • Eat smaller, younger, non-predatory fish • Avoid consumption
Mercury – Organic (methylmercury)	Contaminated fresh water and saltwater fish and marine mammals		• Predatory fish with higher levels of mercury: Shark, swordfish, fresh and frozen tuna, escolar, marlin and orange	Short to long-term exposures to very high levels of methyl mercury, may cause: paresthesia, malaise and blurred vision, concentric	of fish from water bodies identified as being contaminated • Young children and women of child bearing age should limit consumption of fish known to contain mercury

			roughy, and freshwater fish (that feed on other fish) that may have elevated levels of mercury: Northern pike and walleye • Fish-eating birds with high levels of mercury: loons, merganser ducks, osprey, eagles, herons, and kingfisher • Predatory mammals (e.g., otters)	constriction of the visual field, deafness, dysarthria, and ataxia High exposures, may lead to: coma and death In the developing fetus, exposure may affect: the developing nervous system at substantially lower doses than in adults	
Arsenic	Used in the manufacture of a variety of products (e.g., transistors, lasers, and semiconductors,	Surface and ground water including foods grown in contaminated soil	• Meat, poultry, milk and dairy products, bakery goods and cereals, vegetables,	Low levels may cause: • nausea and vomiting, decreased production of red and white	Contact the local environmental health officer if you think the water is contaminated with arsenic

	and in the processing of glass, pigments, textiles, paper, metal adhesives, ceramics, wood preservatives, ammunition, and explosives), also used in the hide tanning process and, to some extent, as a pesticide, feed additive, and pharmaceuticals, including veterinary drugs May enter our environment directly from industrial effluents and indirectly from atmospheric deposition		fruits and fruit juices, fish, and shellfish	blood cells, abnormal heart rhythm, damage to blood vessels, and a sensation of “pins and needles” in the hands and feet, while very high levels of arsenic can result in death Long term exposure through ingestion may cause: • darkening of the skin and the appearance of small “corns” or “warts” on the palms, soles, and torso	

Self-Assessment Exercises 2

1. What are the effects of lead to humans?
2. Distinguish among the three forms Mercury exist

3.5 Summary

Environmental contaminants are those substances which are present in the environment above the permissible limits of concentration, which adversely alters the environment and is toxic to the human, animal and even plant health.

In this unit we have examined naturally occurring and environmental chemical contaminants; environmental contaminants, factors that determine the harmfulness of chemicals in the body, common contaminants found in food and heavy metals.

3.6 Glossary

Agent: Is something that produces or is capable of producing an effect

Algae: They are a diverse group of aquatic organisms that have the ability to conduct photosynthesis

Anti: It is opposed to or against

Applications: The act of putting to a special use or purpose

Bacteria: They microscopic, single-celled organisms that exist in their millions, in every environment, both inside and outside other organisms.

Buffer: Something that gives protection by separating things a protective barrier

Browning: Is the process of food turning brown due to the chemical reactions that take place within.

Chemical: A distinct compound or substance, especially one which has been artificially prepared or purified

Contaminants: A substance that pollutes, spoils, or poisons something:

Emulsifier: Any of numerous chemical additives that encourage the suspension of one liquid in another

Environmental: Relating to the natural world and the impact of human activity on its condition.

Enzymatic: Relating to or involving a substance produced by a living organism which acts as a catalyst to bring about a specific biochemical reaction

Exposure: The fact of experiencing something or being affected by it because of being in a particular situation or place

Food: Any nutritious substance that people or animals eat or drink or that plants absorb in order to maintain life and growth.

Gastrointestinal: The organs that food and liquids travel through when they are swallowed, digested, absorbed, and leave the body as feces

Heavy Metals: It refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations.

Ingestion: The process of taking food, drink, or another substance into the body by swallowing or absorbing it.

Inhibitors: It is a substance or material that slows down or halts some activity

Irritants: A substance that causes slight inflammation or other discomfort to the body.

Microbial: Relating to or characteristic of a microorganism, especially a bacterium causing disease or fermentation

Moulds: A coating or discoloration caused by various saprotrophic fungi that develop in a damp atmosphere on the surface of stored food, fabrics, wallpaper, etc. any of the fungi that causes this growth.

Mushroom: A fungal growth that typically takes the form of a domed cap on a stalk, with gills on the underside of the cap

Mycotoxins: They are toxic fungal products that are produced when fungi grow in human and animal foods.

Natural: In or derived from nature; not made or caused by humankind

Nonenzymatic: Relating to a process not produced by enzymes

Preservative: It is a substance or a chemical that is added to products such as food products, beverages, pharmaceutical drugs, paints, biological samples, cosmetics, wood, and many other products to prevent decomposition by microbial growth or by undesirable chemical changes

Regulations: Are rules made by a government or other authority in order to control the way something is done or the way people behave.

Sequester: To form a chelate or other stable compound with (an ion, atom, or molecule) so that it is no longer available for reactions

Symptoms: A physical or mental problem that a person experiences that may indicate a disease or condition

Synthetic: A compound made artificially by chemical reactions

Toxic: Harmful, causing or capable of causing harm; unhealthful; detrimental to good health; noxious; injurious to physical or mental health

4.7 References/Further Reading

Food Safety for First Nations People of Canada: A Manual for Healthy Practices retrieved from https://dhss.alaska.gov/dph/Epi/eph/Documents/FNIHBFFoodManual.pdf

3.8 Possible Answers to Self-Assessment Exercises

Self-Assessment Exercises 1

1. The effect of the chemical on the body depends on the following factors:-

    a. Route of exposure (e.g., skin contact/dermal absorption, inhalation, or ingestion)

    b. Amount entering the body

    c. Characteristics of the chemical (e.g., toxicity, rate of removal from the body)

    d. Biological variation of humans.

2. Biomagnification is the result of the accumulation of a chemical in an organism at higher levels than are found in its food supply. It occurs when a chemical becomes more concentrated as it moves up through the food chain. For example, animals that eat other animals and plants consume all the contaminants that their food sources were exposed to. As a result, the animals at the very top of the food chain are exposed to the highest levels of contaminants.

Self-Assessment Exercises 2

1. The effects of lead to humans

    a) Acute exposure may cause: convulsions and memory loss

    b) Chronic exposure may cause: muscle weakness, loss of appetite, abdominal pain, constipation, sleeplessness, irritability, headache, impaired mental function, impaired visual and motor performance, brain and kidney damage, damage to the nervous and reproductive systems, and weakness in fingers, wrists, or ankles

c) In men, high exposure levels may: damage the organs responsible for sperm production.

d) In pregnant women may cause: miscarriages and stillbirth

e) In young children may cause: decreased IQ, developmental delays, hearing problems, and behavioural disturbances

2. Mercury exists in three forms:

   i. Elemental (metallic) mercury is the pure form of mercury. It is a heavy, shiny, silver-white volatile liquid that releases a colourless and odourless toxic vapour at room temperature. It is the primary form of mercury released into the air by natural processes, such as volcanic activity.

   ii. Inorganic mercury enters the air, water, or soil from the weathering of rocks that contain mercury or from mining ore deposits, burning coal and waste, and from manufacturing plants. It is formed when elemental mercury combines with other elements such as sulphur, chlorine or oxygen to create compounds known as mercury salts.

   iii. Organic mercury is formed when elemental mercury combines with carbon. Microorganisms in the environment can convert inorganic mercury to the organic form of mercury, also known as methylmercury. Methylmercury is a highly toxic organic compound of mercury, and is more toxic than elemental mercury.

MODULE 5

UNIT 1 PERSISTENT ORGANIC POLLUTANTS PESTICIDES

CONTENTS

1.1 Introduction

Persistent organic pollutants (POPs), sometimes known as “forever chemicals”, are organic compounds that are resistant to environmental degradation through chemical, biological, and photolytic processes. They are toxic chemicals that adversely affect human health and the environment worldwide.

In this unit we shall examine Persistent organic pollutants pesticides effects to humans

1.2 Learning Outcomes

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

- state the organochlorine pesticides
- describe the effects of the organochlorine pesticides to humans
- discuss ways of reducing human exposure to each of the organochlorine pesticides

1.3 Persistent Organic Pollutants

Persistent Organic Pollutants (POPs) are released into the environment through a variety of human activities. Some POPS are manufactured for commercial use; these include industrial chemicals, such as PCBs which are used as coolants in electrical transformers, and pesticides such as DichloroDiphenyl-Trichloroethane (DDT) and toxaphene. Other POPs, such as dioxins and furans, are unintentional by-products of combustion processes. POPs are persistent chemicals that bioaccumulate in the food web and may be hazardous to the environment and to human health.

- **POPs in Humans**

POPs tend to bioaccumulate in higher organisms and to biomagnify in the food chain as levels increase from sea plankton through fish, and up to humans. Humans are exposed to POPs through their diet. The health effects of certain POPs are seen mostly in populations that consume large amounts of fish.

1.3.1 Pesticides

Pesticides are used to control pests in order to increase the quantity and quality of a harvest. They may also be applied to harvested food during transportation and/or storage in order to minimize spoilage and losses.

Some pesticides belong to an older class of pesticides called organochlorines. Organochlorines are identified by the presence of chlorine in their structure. They can enter the environment as a result of the application of pesticides, disposal of contaminated waste into landfills, as well as through the release of chemicals from manufacturing plants. They stick to soil or particles in the air and in aquatic systems. The sediments adsorb organochlorines which then bioaccumulate in fish and aquatic mammals. They accumulate in the fatty tissues of animals and animal-derived foods such as fish or dairy products. Examples of organochlorine pesticides are DDT, aldrin, dieldrin, heptachlor, mirex, chlordane, toxaphene, and endrin.

1) **Aldrin & Dieldrin**

Aldrin & dieldrin are both pesticides that were used to control insects in crops and in domestic, forestry and industrial situations. Aldrin is converted to dieldrin in the body, and in the environment by bacteria and sunlight, making deildrin concentrations in the environment higher than would be expected by dieldrin use alone. Dieldrin binds tightly to the soil where it is taken up by plants and breaks down slowly.

- **Aldrin & Dieldrin in Humans**

Aldrin and dieldrin are absorbed by humans through the consumption of contaminated foods or drinking contaminated water. Aldrin and dieldrin accumulate in the fatty tissue of humans.

Examples of foods known to contain aldrin or dieldrin are shellfish from contaminated lakes, root crops, dairy products and meat. Both aldrin and dieldrin are persistent chemicals and are able to build up in the body causing certain health effects (see Table 1).

2) Endrin

Endrin is a synthetic organochlorine pesticide that is found in small amounts in the air and in fields where it was applied for agricultural purposes. It is also found in low levels in ground water and surface water; it clings to the bottom sediments of rivers, lakes and other bodies of water. Endrin may be broken down at high temperatures. The use of endrin has been banned.

- **Endrin in Humans**

Humans are exposed to endrin through contaminated water, foods grown in contaminated soil, and from hazardous waste. Endrin has also been detected in human breast milk and may be a route of exposure for nursing infants.

3) Heptachlor

Heptachlor is a man-made insecticide and termiticide that was used to kill termites in homes, buildings, and other insects in seed grains and food crops. It is a white powder that smells like moth balls. Heptachlor epoxide binds to soil, where it stays for many years, evaporating slowly into the air.

- **Heptachlor in Humans**

Humans are exposed to heptachlor through the consumption of contaminated foods such as fatty tissues from fish and animals, inhalation of vapors, contaminated soil and water, or direct contact with residual heptachlor from pesticide application. In addition, people whose homes have been treated with heptachlor may also be exposed. Since heptachlor can volatilize from soil, people may be exposed to it in the air.

4) Hexachlorobenzene

Hexachlorobenzene (HCB) was used as a pesticide to protect the seeds of onions, sorghum, wheat and other grains against fungus, as well as to make fireworks, ammunition and synthetic rubber.

HCB is a white crystalline solid and is non-soluble in water, which means exposure through drinking water is limited. It is formed as a by-product in the waste streams of chloralkali and wood-preserving plants and also when burning municipal waste. HCB is among the most persistent environmental contaminants because of its chemical stability and resistance to degradation.

Exposure to HCB may occur near industrial sites where it is produced as an unintentional by-product, as a minor part of another chemical product, near hazardous waste sites where it has been discarded. Past disposal methods for industrial wastes containing hexachlorobenzene included incineration, disposal in landfills, discharge to municipal sewage treatment plants, and emission to the atmosphere. At these sites, HCB may be carried in the air on dust particles, although exposure may also occur through contact with contaminated soil.

- **Hexachlorobenzene in Humans**

Exposure in humans is through inhalation of contaminated air, and the consumption of animalderived fatty foods such as milk, other dairy products, meat, poultry, and fish. Infants may be exposed through breast milk.

5) **Mirex**

Mirex is a man-made pesticide that was used mainly to fight ants (especially fire ants), and termites in crops and stored grain. It is also used as a fire retardant in plastic, rubber, paint, paper and electronics. . When released in the environment, mirex breaks down slowly and may stay for many years, binding itself to soil and sediment particles. Mirex has been detected in the air, surface water, soil and sediment, and aquatic organisms. Mirex does not dissolve in water.

- **Mirex in Humans**

People who live in areas where mirex was used or made may have higher levels in their tissues. In addition, exposure may occur through the consumption of contaminated meat and game, as well as fish from contaminated water bodies. Infants may also be exposed through breast milk. In general most people are exposed to very low levels of mirex. Health effects of mirex exposure in humans are not known, although at high levels it may cause damage to the skin, liver, and nervous and reproductive systems.

6) **Dichloro-Diphenyl-Trichloroethane**

Dichloro-Diphenyl-Trichloroethane (DDT) is a man-made pesticide that was used in the past to control mosquitoes and vector borne diseases. It can travel long distances by air and by water. It is absorbed by plants and animals. It adheres strongly to soil where it may stay for a long time, depending on the type of soil, temperature, and the soil moisture. DDT disappears faster when the soil is flooded or wet than when it is dry and is broken down slowly by microorganisms to Dichloro-Diphenyl-Ethylene (DDE) and DichloroDiphenyl-Dichloroethane (DDD) – byproducts of DDT.

- **DDT in Humans**

DDT exposure may occur through breathing contaminated air, drinking contaminated water (near waste sites and landfills) or the consumption of contaminated foods, such as roots and leafy vegetables, meat, fish, poultry and dairy products.

7) Chlordane

Chlordane is a persistent pesticide that was widely used on lawns, gardens, crops, forests, and to control termites in houses, and in wood and wood products. Chlordane enters the environment and is transported long distances through the atmosphere where it remains in the soil for a long time and builds up through the food chain. Chlordane leaves the soil by evaporation to the air, where it may be redistributed by air currents, contaminating areas far from its original application site.

- **Chlordane in Humans**

Exposure to chlordane is through the consumption of contaminated foods, such as meat (from birds, and mammals), root crops grown in contaminated soil, and fish and shellfish caught in contaminated water. Exposure may also occur as a result of chlordane use in the home or workplace for termite control.

The amount of chlordane that enters the body depends on the concentration in the air, food, or water, and the length of exposure. Most chlordane that enters the body leaves in a few days, mostly through the faeces, and in much smaller amounts in urine.

High levels of chlordane affect the nervous and digestive systems and the liver. Inhalation or accidental ingestion of small amounts of chlordane may also cause headaches, irritability, confusion, weakness, vision problems, vomiting, stomach cramps, diarrhea, and jaundice. Large amounts of chlordane taken by mouth can cause convulsions and death in people.

8) Toxaphene

Toxaphene is a persistent pesticide that was widely used in the 1970s to control lice, ticks, mange, and scab mites. It is released into the environment mainly as a result of its use as an agricultural insecticide, and is transported long distances. Toxaphene is also found in soils, surface water, sediments, rainwater, aquatic organisms, and food products, such as root vegetables, meats, and grains.

- **Toxaphene in Humans**

Humans are exposed to toxaphene through the consumption of toxaphene contaminated foods, particularly in the fatty tissues of fish, shellfish and marine mammals from contaminated water bodies.

Once it enters the body, toxaphene rapidly spreads to all organs, where it is quickly broken down in the body and excreted in urine and faeces. Approximately 90% of the toxaphene is eliminated from the body within 24 to 36 hours after entering the body.

High levels of toxaphene in humans may cause damage to the lungs, nervous system, liver and kidneys. Reversible respiratory failure has also been reported from exposure due to inhalation of toxaphene.

Table 1. Persistent Organic Pollutants (POPs) and their effects

Persistent Organic Pollutants (POPs)	Source	Associated foods for animals	Associated foods for humans	Effects in humans	Reducing Exposure
Aldrin & Dieldrin	Areas where pesticides have been used	Plants, roots, and crops grown in contaminated soils	Shellfish and fish from contaminated lakes, dairy products, contaminated meat from wildlife, plants, roots or crops grown in areas where insecticide has been used	May cause: • headaches, dizziness, irritability, vomiting, and uncontrolled muscle movements	• Avoid consumption of fish and sea food from contaminated water bodies • Avoid consumption of foods/crops grown in areas where pesticides were used • Visible fat should be removed from animals prior to cooking • Cook meat and fish using methods that allow the fat to drain (e.g., broil, bake, boil or grill

					the meat) • Any excess fat should be drained after cooking • Follow Federal Provincial Territorial (F/P/T)advice on consumption of wild game and fish
Endrin	Areas where insecticides have been used	Plants, roots, and crops grown in contaminated soils	Wildlife, fish, and plants, roots or crops grown in areas where insecticide has been used	Acute exposure may cause: • headaches, dizziness, nervousness, confusion, nausea, vomiting, convulsions ,and death	• Avoid consumption of fish and sea food from contaminated water bodies • Avoid consumption of foods /crops grown in areas where pesticides were used • Visible fat should be removed from animals prior to cooking • Cook meat and fish using methods

					that allow the fat to drain (e.g., broil, bake, boil or grill the meat) • Any excess fat should be drained after cooking • Follow Federal Provincial Territorial (F/P/T)advice on consumption of wild game and fish
Heptachlor	Areas where insecticides have been used	Plants, roots, and crops grown in contaminated soils	Fish, dairy products, and contaminated fatty meats, and plants, roots or crops grown in areas where insecticide has been used	None known	• Avoid consumption of fish and seafood from contaminated lakes • Avoid consumption of foods/crops grown in areas where pesticides were used • Visible fat should be removed from the animal prior to cooking

					• Cook meat and fish using methods that allow the fat to drain (e.g., broil, bake, boil or grill meat) • Any excess fat should be drained after cooking • Follow Federal Provincial Territorial (F/P/T)advice on consumption of wild game and fish
Hexachlorobenzene	Areas where pesticides have been used	Plants and fish	Fish, milk, dairy products, and plants, roots or crops grown in areas where insecticide has been used	May cause: • liver disease causing red coloured urine, skin sores, change in skin colour, arthritis, and problems of the stomach and nervous system	• Avoid consumption of fish and seafood from contaminated lakes • Avoid consumption of foods /crops grown in areas where pesticides were used • Visible fat should be removed from

					the animal prior to cooking • Cook meat and fish using methods that allow the fat to drain (e.g., broil, bake, boil or grill meat) • Any excess fat should be drained after cooking • Follow Federal Provincial Territorial (F/P/T)advice on consumption of wild game and fish
Mirex	Areas where insecticides have been used	Plants, fish, and crustaceans	Fish, game, and plants, roots or crops grown in areas where insecticide has been used	High levels may cause damage: • To the skin, liver, and nervous and reproductive systems	• Avoid consumption of fish and seafood from contaminated lakes • Avoid consumption of foods /crops grown in areas where pesticides were used

					• Visible fat should be removed from the animal prior to cooking • Cook meat and fish using methods that allow the fat to drain (e.g., broil, bake, boil or grill meat) • Any excess fat should be drained after cooking • Follow Federal Provincial Territorial (F/P/T)advice on consumption of wild game and fish
DDT /DDE/DDD	Areas where pesticide have been used(e.g., homes treated for termites), food grown		Root and leafy vegetables, fatty meat, fish, shellfish, birds, and crops grown in contaminated	Acute exposure may cause: excitability, tremors, and seizures Chronic exposure may	• Avoid consumption of fish and seafood from contaminated lakes • Avoid consumption of foods /crops grown in areas where

	in contaminated soil, and waste sites or landfills		soil	affect: the nervous system In women, DDE can cause: reduction in lactation duration and increased risk for premature baby	pesticides were used • Visible fat should be removed from the animal prior to cooking • Cook meat and fish using methods that allow the fat to drain (e.g., broil, bake, boil or grill meat) • Any excess fat should be drained after cooking • Wash fruits and vegetables in clean water to remove most of the pesticide from the surface • Follow Federal Provincial Territorial (F/P/T)advice on consumption of wild game and fish

Chlordane	Pesticides used on crops	Contaminated plants	Food grown in contaminated soil (e.g., crops), fish and shellfish from contaminated water, birds, and mammals	May cause: • Headaches, nausea, vomiting, poor balance, tremors, and mental confusion	• Eat smaller and younger fish • Cook meat and fish using methods that allow the fat to drain (e.g., broil, bake, boil or grill the meat) • Any excess fat should be drained after cooking • Wash fruits and vegetables in clean water to remove most of the pesticide from the surface • Follow Federal Provincial Territorial (F/P/T)advice on consumption of wild game and fish
Toxaphene	Insecticide contaminated soil and air	Toxaphene contaminated food sources and water	Contaminated food products such as root vegetables, meat, grains,	Acute exposure may cause: • damage to lungs, nervous system, and	• Eat smaller and younger fish • Cook meat and fish using methods that allow the fat to

			fish and shellfish from contaminated water bodies, and beluga whales	kidneys In severe cases, may cause: • death	drain (e.g., broil, bake, boil or grill the meat) • Any excess fat should be drained after cooking • Wash fruits and vegetables in clean water to remove most of the pesticide from the surface • Follow Federal Provincial Territorial (F/P/T)advice on consumption of wild game and fish

Self-Assessment Exercises

1. What are Persistent organic pollutants (POPs)?
2. What are the 12 persistent organic pollutants?

1.4 Summary

POPs not only persist in the environment, but also as they are taken in by animals they bioaccumulate, increasing their concentration and toxicity in the environment. This increase in concentration is called biomagnification, which is where organisms higher up in the food chain have a greater accumulation of POPs.

In this unit we examined Persistent organic pollutants pesticides effects to humans and their bioaccumulation.

1.5 References/Further Reading

Food Safety for First Nations People of Canada: A Manual for Healthy Practices retrieved from https://dhss.alaska.gov/dph/Epi/eph/Documents/FNIHBFFoodManual.pdf

1.6 Possible Answers to Self-Assessment Exercise

1. Persistent organic pollutants (POPs), sometimes known as "forever chemicals", are organic compounds that are resistant to environmental degradation through chemical, biological, and photolytic processes. They are chemicals of global concern due to their potential for long-range transport, persistence in the environment, ability to bio-magnify and bio-accumulate in ecosystems, as well as their significant negative effects on human health and the environment.

2. These were a group of 12 highly persistent and toxic chemicals: aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzen, mirex, polychlorinated biphenyls, polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans, and toxaphen.

UNIT 2 POPs: INDUSTRIAL CHEMICALS, BY-PRODUCTS

CONTENTS

2.1 Introduction

In this unit we shall continue with POPs treated in the previous unit, with our focus now on Industrial chemicals, by products.

2.2 Learning Outcomes

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

- dicuss some industrial chemicals and by products that are POPs
- discuss the ways of reducing human exposure to the POPs
- discuss radionuclides as it relates to POPs
- discuss the polycyclic aromatic hydrocarbons (pahs), polybrominated diphenyl ethers (pbdes), perflourinated chemicals (pfos/pfoa), radionuclides and their effects on humans

2.3 Industrial Chemicals

Industrial chemicals are chemicals that are used for various purposes, for example in fuels, lubricants, flame retardants, or as a fumigant in agricultural products. An example of an industrial chemical is polychlorinated biphenyls (PCBs).

- **Polychlorinated Biphenyls**

PCBs are a group of 209 synthetic organic compounds that were banned in various countries in the late seventies. In the past, many industrial materials, such as sealing and caulking compounds, cutting oils, inks and paint additives, contained PCBs. They were also used to make coolants and lubricants for certain kinds of electrical equipment, such as transformers and capacitors. Today, trace levels of PCBs are found in the environment (air, soil and water) as a result of improper disposal practices. Contamination by PCBs is due primarily to long-range transport.

Once in the environment, PCBs are present as absorbed particles where they easily move (from soil to water, water to air, air to water, sediments to water). PCBs can be carried long distances from where they were released, and eventually return to the land and water, settling as dust or precipitation – rain and snow. Because PCBs do not readily break down, they may remain in the soil for months or years and bioaccumulate in the environment, increasing in concentration up the food chain. This is of special concern in areas where fish are exposed to PCB contamination and may be consumed by humans. PCBs are able to accumulate in the leaves and above-ground parts of plants, including food crops; lighter PCBs leave the soil through evaporation.

- **PCB in Humans**

People are exposed to PCBs primarily from contaminated food such as meat, dairy products, and fish caught in contaminated lakes or rivers, drinking contaminated well water near hazardous waste sites and breathing contaminated air. PCBs tend to accumulate in the fatty tissues of animal-derived foods and people who eat large amounts of sport fish, wildlife or marine mammals may be exposed to higher dietary levels.

Once in the body, some PCBs may be transformed into other related chemicals called metabolites which may be as harmful as some unchanged PCBs. Some of these metabolites may leave the body in the faeces within a few days, although others may remain in fatty tissues for months. PCBs may be stored for years mainly in the fat and liver, but smaller amounts can be found in other organs as well. Effects of PCBs in humans may include skin conditions, liver, neurologic and gastrointestinal effects.

Self-Assessment Exercises 1

1. What are PCBs and why are they harmful?
2. Are PCBs still used today?

2.4 By Products

Polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) are toxic chemicals commonly known as dioxins and furans. Dioxins and furans are found in very small amounts in the environment, including air, water, and soil. There are over 200 different dioxins and furans, but only 17 are known to be toxic and to bioaccumulate in food. The most toxic chemical in the group is 2,3,7,8-tetrachlorodibenzop-dioxin (TCDD) and other dioxins are measured in relation to TCDD.

Dioxins can also be produced from natural processes, such as forest fires and volcanic eruptions. The airborne chemical can attach to small particles that can travel long distances in the atmosphere. Exposure to dioxins can occur through the consumption of food grown in contaminated soils. Levels of dioxins in soil are higher than levels in both air and water.

- **Dioxins in Humans**

Humans are exposed to dioxins through the consumption of contaminated foods, particularly dairy products, fish, and meat. Dioxins may also be present in fruits and vegetables, although at much lower levels. Low levels of dioxins have also been measured in breast milk, and in infant formula.

- **Furans in Humans**

People are exposed to very low levels of furans through inhalation, drinking water, and consumption of furan contaminated foods, such as meat and other meat products, fish and fish products, and milk and milk products. Because furans concentrate in fatty tissues, consuming large amounts of fatty fish from water contaminated by furans may increase one's exposure from food.

- **Dioxins and Furans and Animals**

Both dioxins and furans accumulate in the fatty portions of animals, hence, meat, milk products and fish have higher levels of dioxins and furans than fruit, vegetables and grains. Visible fat can be trimmed from foods such as meat and fish and should be prepared in ways that allow the fat to drain. Effects of dioxins on animals include decreased food consumption and slowed growth.

- **Polybrominated diphenyl ethers (PBDEs)**

Polybrominated diphenyl ethers (PBDEs) are a group of chemical substances used as flame retardants and are persistent in the environment. PBDEs enter the environment during their manufacture, and have been measured in air, soil, sediment, and water often far from sources of release. They do not dissolve easily in water, but can stick to particles and settle to the bottom of rivers or lakes, where some can accumulate in fish.

— **PBDEs in Humans**

Primary sources of human exposure to PBDEs are through the consumption of contaminated foods such as the fatty tissues of meat and fish, dairy products, and food crops grown in contaminated soils.

- **Perflourinated Chemicals**

Perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) are both man-made chemicals that belong to a family of compounds known as perflourinated chemicals (PFCs). PFOS and PFOA are the most common PFCs, and are extremely persistent with bioaccumulating and biomagnifying properties.

PFCs can be found in the air, soil, and water after release from use and disposal of products that contain these chemicals. PFCs do not break down in water or soil, and can be found and may be carried long distances by ocean currents, or through soil by ground water. Due to their persistence and widespread use, PFCs have been detected in low concentrations in the environment, in food and wildlife such as polar bears, and some bird species.

— PFOs/PFOA in Human

Exposure to PFOS/PFOA in humans may occur through the consumption of contaminated food or drinking water, or breathing contaminated air. PFOS/ PFOA can stay in the body for many years. Exposure to certain PFCs, in particular PFOS and PFOA, has been associated with various adverse health effects in laboratory animals, including immune, liver and thyroid function.

- **Polycyclic Aromatic Hydrocarbons**

Polycyclic aromatic hydrocarbons (PAHs) belong to a group of over 100 different chemicals that are released into the environment from different sources such as forest fires and the incomplete burning of coal, oil, gas, garbage and other organic substances such as tobacco. Anthropogenic PAHs are found in coal tar, crude oil, creosote and roofing tar, and a few are used in medicines, dyes, plastics, and pesticides (see Table 2).

When released into the environment, PAHs can readily break down over a period ranging from a few days to several weeks. Most PAHs do not dissolve in water and are found in the bottoms of rivers or lakes. Major sources of PAHs in aquatic and soil environments are creosote-treated products, spills of petroleum products and metallurgical and cooking plants.

— PAHs in Humans

Exposure in humans is through breathing contaminated air from cigarette smoke, wood smoke, vehicle exhaust, smoke from agricultural burns, water or soil near hazardous waste sites, and consumption of contaminated foods, such as meats and fish (from contaminated waters). PAHs can also be found in foods that have been grilled or charbroiled. The method of cooking, preservation, and storage of foods is a factor in PAH exposure. PAH exposure may cause lung cancer in humans.

- **Radionuclides**

Radionuclides are radioactive contaminants that occur naturally as trace elements in rocks and soils (such as polonium and uranium), or result from the deposition of airborne, man-made radionuclides (such as cesium and strontium). Radionuclides release energy in the form of radiation. Examples of radionuclides include: cesium, polonium, strontium, and radium.

— **Cesium**

Cesium is a persistent man-made radionuclide that was released during nuclear weapons testing and by the Chernobyl nuclear accident. Levels of cesium in the environment have dropped since the 1960s, and are not considered a health risk to caribou or to the people who eat them.

— **Polonium**

Polonium is the most commonly found natural radionuclide and is known to build up in caribou when they eat lichen.

— **Uranium**

Uranium is also a natural radionuclide that can be found in increased levels as a result of uranium mining, and is found in both ground water and surface water. Humans are exposed to uranium through ingestion of contaminated food or water.

— **Strontium**

Strontium is said to be the most important because of its long radiation half-life of 29 years. Strontium is found in the environment as a result of nuclear fallout during atmospheric weapons tests, and accumulates in bones and teeth.

— **Radium**

Radium (includes Radium-226 and Radium-228) is found in small amounts in natural ground water.

- Most radionuclides found in food sources are of natural origin.

Factors that can lead to ingestion of radionuclides include:

- radioactively contaminated drinking water (e.g., polluted ground water).
- locally grown food plants that take up certain soil radioactivity.
- use of radioactively contaminated water to irrigate crops.
- local livestock operations, when radionuclides that accumulate in animal tissue are present.
- consumption of fish with radioactivity from local bodies of water.

Plants and lichens absorb radionuclides through the soil and air. Humans can be exposed to radionuclides through the consumption of contaminated foods, such as caribou, which feed on lichens. Exposure to radionuclides in traditional food is not considered to be a health concern.

Table 1. Persistent Organic Pollutants (POPs) and their effects

Persistent Organic Pollutants (POPs)	Source	Associated foods for animals	Associated foods for humans	Effects in humans	Reducing Exposure
Polychlorinated biphenyls (PCBs)	Capacitors, transformers, and hydraulic fluids.	Contaminated water and food crops grown in contaminated soil	Caribou, muskox, moose, beluga whale and seal (blubber), migrating birds, bald eagle eggs, fish (e.g., Chinook salmon), And sea otters, meat, fish, dairy products, poultry, and eggs	May cause: • Skin conditions, liver, neurologic And gastrointestinal effects	• Visible fat should be removed from the animal prior to cooking • Cook meat and fish using methods that allow the fat to drain (e.g., broil, bake, boil or grill the meat) • Any excess fat should be drained after cooking • Follow Federal Provincial Territorial (F/P/T)advice on consumption of wild game and sport fish

Dioxins and Furans	Industrial processes (e.g., bleaching paper pulp, chemical and pesticide manufacture), combustion activities (e.g., forest fires and waste incineration), and treated wood (dioxins)		Herring, mackerel, salmon, sardines, trout, and tuna, meat, dairy products, poultry, and eggs	May include: • skin disorders (e.g., chloracne), liver problems, impaired immune and endocrine systems and reproductive functions, effects on the developing nervous system, and certain types of cancers	• Skin the fish prior to cooking. • Trim all visible fat from meat and fish • Cook meat and fish using methods that allow the fat to drain (e.g., broil, bake, boil or grill the meat) • Any excess fat should be drained after cooking • Follow Federal Provincial Territorial (F/P/T)advice on consumption of wild game and fish

Table 2. **Polycyclic aromatic hydrocarbons (PAHs), Polybrominated diphenyl ethers (PBDEs), Perflourinated chemicals (PFOS/PFOA), radionuclides and their effects**

Contaminants	Source	Associated foods for animals	Effects in humans	Reducing Exposure
Polycyclic aromatic hydrocarbons (PAHs)	Forest fires, burning coal, coal tar, crude oil, spills from petroleum products, garbage, tobacco, creosote and creosote-treated products, roofing tar, medicines, dyes, plastics, pesticides, and char broiled foods.	Grilled or charred meat, milk, cereals, flour, bread, vegetables, fruits, and processed or pickled foods	May cause: lung cancer	• Reduce consumption of grilled or charred meats or fish and/ or cut away any charred portions of food • Eat a variety of foods from different sources (Refer to Canada's Food Guide or Eating Well with Canada's Food Guide - First Nations, Inuit and Métis)

Polybrominated diphenyl ethers (PBDEs)	Flame retardants added to plastics and foam products	Meat, fish, dairy products, and food crops grown in contaminated soils	No information on health effects on people	• Eat a variety of foods from different sources. (Refer to Canada's Food Guide or Eating Well with Canada's Food Guide - First Nations, Inuit and Métis) • Trim fatty tissue from meat before cooking and employ cooking methods that allow the fat to drain
Perflourinated chemicals (PFOS/PFOA)	Disposal of products that contain perflourinated compounds	Polar bears, some bird species, and foods grown in contaminated soils	No significant risk to human health	• Eat a variety of foods from different sources. (Refer to Canada's Food Guide or Eating Well with Canada's Food Guide - First Nations, Inuit and Métis)
Radionuclides	Naturally, through rocks or soils or man-made through testing of nuclear weapons,	Lichen, caribou, fish, beluga, and waterfowl	No effects at low levels	Eat a variety of foods from different sources

	nuclear waste dumping, mining			

Self-Assessment Exercises 2

1. What effects does Dioxins and Furans have on humans?
2. State the factors that can lead to ingestion of radionuclides

2.5 Summary

POPs: Industrial chemicals, by products mostly result from various human activities like manufacturing, handling, storing and disposal of chemicals. These occur in industrial places and activities such as oil refineries, coal power plant, construction, mining & smelting and transportation.

In this unit we continued with POPs, focusing on Industrial chemicals, by products, polycyclic aromatic hydrocarbons (pahs), polybrominated diphenyl ethers (pbdes), perflourinated chemicals (pfos/pfoa), radionuclides and their effects.

2.6 References/Further Reading

Food Safety for First Nations People of Canada: A Manual for Healthy Practices retrieved from https://dhss.alaska.gov/dph/Epi/eph/Documents/FNIHBFFoodManual.pdf

2.7 Possible Answers to Self-Assessment Exercises

Self-Assessment Exercises 1

1. PCBs, or polychlorinated biphenyls, are highly toxic industrial compounds. They pose serious health risks to fetuses, babies and children, who may suffer developmental and neurological problems from prolonged or repeated exposure to small amounts of PCBs. These chemicals are harmful to adults as well.
2. Commercial production of PCBs ended in 1977 because of health effects associated with exposure. In 1979, the U.S. Environmental Protection Agency (USEPA) banned the use of PCBs; however, PCBs are still present in many pre-1979 products.

Self-Assessment Exercises 2

1. The effects of Dioxins and Furans on humans May include: skin disorders (e.g., chloracne), liver problems, impaired immune and endocrine systems and reproductive functions, effects on the developing nervous system, and certain types of cancers
2. Factors that can lead to ingestion of radionuclides include:
    a) radioactively contaminated drinking water (e.g., polluted ground water).
    b) locally grown food plants that take up certain soil radioactivity.
    c) use of radioactively contaminated water to irrigate crops.
    d) local livestock operations, when radionuclides that accumulate in animal tissue are present.
    e) consumption of fish with radioactivity from local bodies of water.

UNIT 3 ANTINUTRIENTS 1

CONTENTS

3.1 Introduction

Antinutrients are natural or synthetic compounds that interfere with the absorption of nutrients. Nutrition studies focus on antinutrients commonly found in food sources and beverages.

In this unit we shall examine Antinutrients, the antinutritional factors significant in human food and animal feed.

3.2 Learning Outcomes

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

- discuss the antinutritional factors significant in human food or animal feed
- discuss on the source, mode of action, effects, beneficial of some antinutrients
- evaluate the categories of antinutritional

3.3 Antinutrients

The antinutrients refer to defence metabolites, having specific biological effects depending upon the structure of specific compounds which range from high molecular weight proteins to simple amino acids and oligosaccharides.

These secondary metabolites play a role in defence again herbivorous, insects, pathogens or adverse growing conditions.

Antinutrient substances from nutritional point of view, interferes with normal growth, reproduction and health, when consumed regularly in amount existing in a normal component of diet therefore should be considered as harmful and toxic. A significant part of human population relies on legumes as staple food for subsistence, particularly in combination with cereals. They are unique foods because their rich nutrient content includes starch, protein, dietary fibre, oligosaccharides, phytochemicals (especially the isoflavons in soybean) and minerals. Their nutritional content contributes to many health benefits to humans. So, the knowledge regarding various anti-nutritional substances present in foods as well as techniques to reduce them in the diet is essential for health and wellbeing of the population.

- **Classification**

The antinutritional factors in plants may be classified on the basis of their chemical structure, the specific actions they bring about or their biosynthetic origin. Although, this classification does not encompass all the known groups of anti-nutritional factors, it does present the list of those frequently found in human foods and animal feedstuffs.

- **Categorization**

The antinutritional factors may be divided into two major categories. They are:

1) Proteins (such as lectins and protease inhibitors) which are sensitive to normal processing temperatures.
2) Other substances which are stable or resistant to these temperatures and which include, among many others, polyphenolic compounds (mainly condensed tannins), non-protein amino acids and galactomannan gums.
   - More often than not a single plant may contain two or more toxic compounds, generally drawn from the two categories which add to the difficulties of detoxification.

3.3.1 Antinutritional Factors Significant in Human Food or Animal Feed

They include the following-

- Enzyme inhibitors (trypsin and chymotrypsin inhibitors, plasmin inhibitors elastase inhibitors),
- Haemaglutinnins (concanavilin A, ricin),
- Plant enzyme (urease, lipoxygenase),
- Cyanognic glycoside (phaseolunatin, dhurrin, linamarin, lutaustrailin),
- Goitrogens (pro-goitrins and glucosinolats)
- Oestrogens (flavones and genistein),
- Saponins (soya sapogenin),
- Gossypol from *Gossypium species* e.g cotton
- Tannins (condensed and hydrolysable tannins)

- Amino acid analogues (BOAA, DAP, mimosine, N-methyl-1 alanine,
- Alkaloids (solanine and chaonine),
- Anti-metals (phytates and oxalates)
- Antivitamins (antivitamins A.D. E. and B12) and
- Favism factors.

- **Protease(trypsin) and amylase inhibitors**
  - **Source**

Protease inhibitors are widely distributed within the plant kingdom, including the seeds of most cultivated legumes and cereal.

Protease inhibitors have the ability to inhibit the activity of proteolytic enzyme within the gastrointestinal tract of animals. Due to their particular protein nature, protease inhibitors may be easily denatured by heat processing although some residual activity may still remain in the commercially produced products. The antinutrient activity of protease inhibitors is associated with growth inhibition and pancreatic hypertrophy.

Trypsin inhibitor and chymotrypsin inhibitors occurring in raw legume seeds.

- **Mode of Action**

Trypsin inhibitors are unique class of proteins found in raw soybeans that inhibit protease enzymes in the digestive tract by forming indigestible complexes with dietary protein.

- **Effects:**

Negative: The antinutrient activity of protease inhibitors is associated with growth inhibition and pancreatic hypertrophy.

- **Beneficial**

Lower incidences of pancreatic cancer have been observed in populations where the intake of soybean and it products is high. They may also act as anti-carcinogenic agents.

The Bowman-Birk inhibitors derived from soybean have been shown to inhibit or prevent the development of chemically-induced cancer of the liver, lung, colon, oral and oesophagus

- **Haemagglutinins**

Haemmagglutinins are proteins in nature and are sometimes referred to as phytoagglutinins or lectins.

- **Source:**

Sources are as in legumes; most cereals commonly consumed by human contain glycoprotein called lectins.

- **Mode of action**

Many lectins can bind to intestinal epithelial cells, where they may impair nutrient absorption and cause damage that may allow infiltration of bacteria into the blood stream.

- **Health Effects**

If some types of beans are consumed raw, they may cause shock cramps.

- **Saponins**

Saponins are a heterogeneous group of naturally foam producing triterpene or steroidal glycosides that occur in a wide range of plants.

- **Source**

Saponins occurs in broad range of plants consumed in the human diet including legumes (soy, peas and beans), root crops (potato, yam, asparagus and allium) as well as in oats, sugar beet, tea and many medicinal herbs.

- **Health Effects**

Negative: Saponins reduce the uptake of certain nutrients including glucose and cholesterol at the gut through intraluminal physicochemical interaction.

Toxic saponins cause nausea and vomiting

- **Beneficial:**

Hypocholesterolemic effects in man

- **Phytates**

Phytate (is also known as Inositol hexakisphosphate (InsP6) is the salt form of phytic acid, are found in plants, animals and soil. It is primarily present as a salt of the mono and divalent cations K+, $Mg2^{+}$, and Ca2+ and accumulate in the seeds during the ripening period. Phytate is regarded as the primary storage form of both phosphate and inositol in plant seeds and grains. In addition, phytate has been suggested to serve as a store of cations, of high energy phosphoryl groups, and by chelating free iron, as a potent natural anti-oxidant.

- **Source**

In monocotyledons such as wheat and rice, phytates is present in germ of corn and in the aleurone or bran layer allowing an easy separation by milling. However, in diacotyledons seeds such as legumes, nuts and oilseeds, phytates are found closely associated with proteins and is often isolated or concentrated with protein fraction of these foods. They can be regarded as stores for phosphate and mineral nutrients that are important for plant nutrition and especially vulnerable during germination.

- **Health Effects**

Negative- Phytic acid and Phytate have a strong binding affinity to the dietary minerals- zinc, iron magnesium and calcium, inhibiting their absorbtion in the small intestine and thereby causing mineral deficiency in animals and humans.

- **Oligosaccharides and Iso Flavonoids:**

Legume seeds are generally rich in oligosaccharides (up to 20%), such as stachyose and raffnose. These compounds serve as carbon source during germination therefore, their contents can be reduced in legumes through germination which is common practice, e.g. in soybeans.

- **Source**

Iso flavonoids have been detected in soyaben, lupins and several other legumes. They are involved in plant defence again fungi, bacteria, viruses and nematodes (phytoalexins, phytoanticipins) act as signals in Legume-Rhizobium and exhibit estrogenic activities.

- **Health Effects**

Since, these enzymes are often stimulated in cancer cells, the lower incidence of some kinds of cancers in people which ingest isoflavone rich food, such as soybean products, has stimulated the hypothesis, that some legumes rich in **isoflavones can prevent cancer.**

- **Cynogenic Glycosidases**

The cyanogenic belong to the products of secondary metabolism, to the natural products of plants. These compounds are composed of an a-hydroxynitrile type aglycone and of a sugar moiety (mostly D-glucose). Cyanogenic glucosides (a-hydroxynitrile glucosides) are derived from the five protein amino acids Val, lle, Leu, Phe and Tyr and from the nonproteinogenic amino acid cyclopentenly glycine. Although derived from six different building blocks, they constitute a very small class with around 50 different known structures. A number of plant species produce hydrogen cyanide (HCN) from cyanogenic glycosides when they are consumed. These cyanogens are of a sugar, often glucose, which is combined with a cyanide containing aglycone.

Cyanogenic glucosides are classified as phytoanticipins. Their general function in plants is dependent on activation by b-glucosidases to release toxic volatile HCN as well as a ketones or aldehydes to fend off herbivore and pathogen attack.

- **Source**

Cassava is a crop plant rich in cyanogenic glycosides.

- **Health Effects**

Chronic exposure to HCN may cause neurological, respiratory, cardiovascular and thyroid defects. Onset of symptoms depend on dose and duration of exposure. Large scale of cassava processing could lead to discharge of hydrocyanic acid into the air.

- **Vicine and Convicine: (Favism factors)**

Favism in a hemolytic disease that is found in sensitive individuals with consumption of broad beans. It is more widely found in people living in the Mediterranean countries.

- **Mode of Action**

The structure of hemoglobin, which is the primary carrier of oxygen, is upset.

- **Health Effect**

Dizziness, vomiting, feeling of tiredness and dark orange urine, which is the first symptoms of the disease. The disease disappears soon but incidences of death may be encountered when the disease is prolonged. This disease of hemolytic anemia is caused by favogens.

- **Lupin Alkaloids**

In its raw form, the mildly toxic lupin alkaloids present in plants causes a bitter taste, and used as defensive mechanism against herbivorous.

- **Non-protein amino acids**

Hundreds of types of non-protein amino acids have been found in nature and they have multiple functions in living organisms. Microorganism and plants can produce uncommon amino acids.

- **Health Effect**

The effect of misincorporation of non-protein amino acids can result in defective structure and function. One common effect is aggregation and tangling of proteins.

Self-Assessment Exercises

1. What are antinutrient
2. State the categories of the antinutritional factors
3. State the antinutritional factors significant in human food or animal

1.4 Summary

Antinutrients are found at some level in almost all foods for a variety of reasons. However, their levels are reduced in modern crops, probably as an outcome of the process of domestication.

In this unit we examined Antinutrients, the antinutritional factors significant in human food and animal feed.

1.5 References/Further Reading

Aletor V.A (2005). *Anti-nutritional factors as Nature's Paradox in Food and Nutrition Securities.* Inaugural lecture series 15 delivered at the Federal University of Technology, Akure (FUTA)

Hedley C.L. Introduction 2001, In: Carbohydrates in Grain Legume Seeds (Ed. C.L. Hedley) CAB International, pp.1-1

K. O. Soetan and O.E. Oyewol, 2009, The need for adequate processing to reduce the anti-nutritional factors in plants used as human foods and animal feeds. *African Journal of Food Science Vol. 3(9), pp. 223-232, September, 2009. ISSN 1996-0794 C 2007 Academic Journals.*

Muahamad Nadem et al. (2010) An overview of anti-nutritional f actors in creal grains with special reference to wheat –A review Pakistan Journal of Food Sciences (2010). Vol. 20 Issue 1-4, Page(s):54-1.

P. Kiranmayi, Is Bio Active Compounds Inplantsacts as Anti-Nutritional Factors

Panhwar F.(2005). Anti-nutritional factors in oil seeds as aflatoxin in ground nut. Retrieved from www.ChemLin.com

Santosh Khotar Anti-nutritional Factors in Food Legumes and Effects of Processing The Role of Food, Agriculture, Forestry and Fisheries in Human Nutrition.

Sarajejvo, 2009, Anti-nutritional Factors in Food Grain Legumes, 1st International Syposium on Sustainable Development, June, 9-10, 40.

Soetan K. and Oyewol O. (2009) The need for adequate processing to reduce the antinutritional factors in plants used as human foods and animal feeds: A review. Africa Journal of Food Science Vol. 3(9), pp. 223-232.

Ugwu, F.M. and Oranye, N.A. (2006). Effects of some processing methods on the toxic components of African breadfruit (Treculia Africana) African Journal of biotechnology 5,2329-2333.

1.6 Possible Answers to Self-Assessment Exercise

1. The antinutrients refer to defence metabolites, having specific biological effects depending upon the structure of specific compounds which range from high molecular weight proteins to simple amino acids and oligosaccharides.

2. The antinutritional factors may be divided into two major categories. They are:Proteins (such as lectins and protease inhibitors) which are sensitive to normal processing temperatures. Other substances which are stable or resistant to these temperatures and which include, among many others, polyphenolic compounds (mainly condensed tannins), non-protein amino acids and galactomannan gums.More often than not a single plant may contain two or more toxic compounds, generally drawn from the two categories which add to the difficulties of detoxification.
3. They include the following-
    a. Enzyme inhibitors (trypsin and chymotrypsin inhibitors, plasmin inhibitors elastase inhibitors),
    b. Haemaglutinnins (concanavilin A, ricin),
    c. Plant enzyme (urease, lipoxygenase),
    d. Cyanognic glycoside (phaseolunatin, dhurrin, linamarin, lutaustrailin),
    e. Goitrogens (pro-goitrins and glucosinolats)
    f. Oestrogens (flavones and genistein),
    g. Saponins (soya sapogenin),

h. Gossypol from *Gossypium species* e.g cotton

i. Tannins (condensed and hydrolysable tannins)

j. Amino acid analogues (BOAA, DAP, mimosine, N-methyl-1 alanine,

k. Alkaloids (solanine and chaonine),

l. Anti-metals (phytates and oxalates)

m. Antivitamins (antivitamins A.D. E. and B12) and

n. Favism factors.

UNIT 4 ANTINUTRIENTS 2

CONTENTS

4.1 Introduction

Antivitamins are substances that inhibit the biological function of a genuine vitamin. Some antivitamins have a similar chemical structure to those of the actual vitamins whose action they block or restrict.

In this unit we shall continue from the previous unit with antinutrient with our emphasis now on antivitamins.

4.2 Learning Outcomes

At the end of this unit you should be able to

- discuss on the various types of antivitamins
- discuss the processes that reduce or eliminate the effects of antinutrients

4.3 Antivitamins

Food antivitamins are substances present in the diet that prevent the assimilation, absorption or metabolism of vitamins. All of them are classified within antinutrients.

These components are not very abundant in the diet, because they are normally destroyed during cooking or they are not ingested in sufficient quantities to produce nutritional deficiencies.

4.3.1 Types of Antivitamins

- **Antivitamin k or Coumarin Factor**

Coumarins are vitamin k antagonists that produce their anticoagulant effect by interfering with the cyclic interconversion of vitamin k and its 2,3 epoxide(vitamin k epoxide). The anticoagulant effect of coumarins when consumed in excess may lead to bleeding in a situation where there is injury.

Foods that have an important content in coumarins are: grapefruit, alfalfa (in the form of sprouts or as an edible wild plant) and capers.

People taking anticoagulant medications should take special care not to eat these foods, since their coumarins enhance the effect of the drugs and the risk of bleeding multiplies.

- **B1 or Thiamin antivitamin factors**

Some foods contain substances that inhibit the assimilation of thiamin or vitamin B1. This vitamin (B1) is abundant in many foods, both vegetable and animal, so the ingestion of antivitamin B does not pose a nutritional problem or lead to serious health damage in the vast majority of cases.

- **The main antivitamin B1 factors are**:
  - Thiamines type I: They are enzymes that destroy vitamin B1. They are found in meat liver, pates and seafood (clams, crabs, ...). These components are removed with cooking, so they are only found in meat and fish that are eaten raw or undercooked, other thiamines can be found in plants. Vegetables in the cabbage family (cruciferous) also contain B1 anti-vitamin factors.
- **Analogs of Thiamine**
  - Two analogs of Thiamine, oxythiamine and pyrithiamine are potent antimetabolites that are widely used to induce thiamine deficiency in experimental animals.

    - **Sulfites**

    The use of sulphites in food reduces the vitamin B1 (Thiamine) content of the food. Sulfites are the food additives numbered in Europe from number E220 to B228. These additives are used to inhibit growth of microbes in food and to preserve the vivid color of food (antioxidant). They are found in industrial fruit nectars, burger meat, and dried fruits such as dried apricots.

Thiamine is labile to sulphite, which cleaves the methylene bridge leading to loss of thiamine. Sulfite treatment of dried fruit and other foods results in more or less complete loss of thiamin.

- **Egg avidin or antivitamin B8 (biotin)**

Avidin is an abundant antivitamin in egg while that binds to two biotin molecules (vitamin B8) forming a compound that prevents the absorption of this vitamins.

This substance is removed by cooking the egg, so it is only found in the raw egg or raw egg white. This is one of the reasons why eating raw eggs or using raw egg remedies is not recommended.

In addition, the consumption of uncooked egg has other drawbacks such as the possibility of of food poisoning and indigestion. Once cooked, egg proteins and vitamins are easier to digest.

There are usually no cases of biotin deficiency due to egg ingestion, because food is always consumed cooked. However, biotin deficiencies can occur in people who consume raw eggs or raw egg yolks daily.

- **Antivitamin C Factors in fruits**

Vegetables and fruits of the cucurbitaceae family such as melon, watermelon, cucumber, chayote or zucchini contain an enzyme (ascorbic acid oxidase) that inactivates vitamin C. it is also present in fresh fruits, although in practically insignificant quantities.

This enzymes is destroyed in cooking (although cooking itself also eliminates vitamin C, which is heat sensitive). It should be mentioned that there are many other antioxidant components in addition to vitamin C, such as flavonoids, substances that are also abundant in vegetables. It will be very beneficial to increase the vitamin intake of the diet, adding foods very rich in vitamin C fruits and vegetables.

- **Others food antivitamin factors**

-Antivitamin B3 or niacin factors: there are antivitamins that affect the correct absorption of niacin (niacinogens). Very well-known is the case of corn which needs an alkaline bath so that the vitamin B3 it contains is assimilable (a process known as nixtamalization).

-Antivitamin A Factors: soy contains the enzyme lipoxidase, which inactivates vitamin A and beta carotene from fruits and and vegetables. He citral present in the essential oil of citrus fruits (especially in the skin of thee fruits), also has an antivitamin A.

-Antivitamin E Factors: In the fatty fraction of some herbs substances that eliminate vitamin E have been found, such as in alfalfa.

-Antivitamin D Factors: raw soybeans have a substance that can cause rickets, which is vitamin D deficiency. It is not a toxicological problem since it is eliminated during cooking.

- **Vitamin B12 Analogues**

In the algae there are substances that are analogous to vitamin B12, that is, they are very similar substances but without vitamin function.

It is not exactly a type of antivitamin, because these analogues do not prevent the absorption of function of true vitamin B12, but it should be taken into account in vegetarians, since it is a problem in the diagnosis of vitamin B12 deficiency.

- **Toxicity of Antivitamins**

In general, antivitamins are not toxic in the doses found in the diet although they diminish the nutritional value of food. The scarce problem of these substances is due to the fact that most are destroyed during food preparation. However, they do have important contraindications in some cases.

4.3.2 Processes that reduce or eliminate the effects of antinutrients

1) Thermal treatment

Legume seeds are hardly been consumed raw, they are usually cooked and by this procedure, lectins and protease inhibitors are inactivated.

Low molecular weight compounds are leached out into cooking water, to be discarded afterwards.

Antinutritional Factor	Common Food Sources	Effect of Antinutritional Factor
Avidin	Egg Whites, Red Kidney, Beans	Binds biotin making it biologically unavailable
Haemagylutins	Yellow Wax Beans, Chick Pea	Binds biotin
Lathyrogens	Sweet Potatoes, Beans	Disturbances in the electric fibre formation of the vascular wall
Goitrogens	Cabbage, Turnips	Induced red Blood cells clumping in iodine deficiency
A-Amylase inhibitors	Cereal grains	Prevent the action of enzymes that break the glycosidic bonds
Typsin inhibitors	Peas, Beans, Legumes	Decreases growth rate by reducing protein digestion
Thiaminase	Fish, Shellfish, Red Cabbage, Brussels Sprouts	Causes thiamine deficiency

2) Chemical Detoxification

Deaminocanavanine is is a well-known nontoxic deamination product of canavanine. The degradation of canavanine to deaminocanavanine under alkaline conditions occurs therefore a chemical strategy for the detoxification of this compound has already been successfully employed for the processing of the canavanine containing seeds of *C. ensiformis.* It is reasonable to propose that in principle post-harvest detoxification procedures can be developed for these anti-nutritional factors.

3) Fermentation

The incorporation of fermentation processes in simple food technologies offer good prospects for a detoxification of food source of antinutrients while simultaneously giving flexibility in the manipulation of flavour, texture and colour of the raw material.

4) Germination

Pea and lentil sprouts have gained popularity in recent years. Traditionally, Mediterranean, grain legumes have not been used as sprouts, the potential toxicity of beta-isoxazolin-5-one-alanine (BIA), the biosynthetic precursor for the lathyrism toxin beta-ODAP (Oxalyldiaminopropionic acid –ODAP) may be a risk factor if consumption increases during the germination of lentils and peas.

The kind of processing, however, which reduces the content of oligosaccharides and of other N-containing ANFs, has a long history in Asia, where it has served to improve the palatability of soybeans.

Self-Assessment Exercises

1. What are antivitamins?
2. Discuss Antivitamin k or Coumarin Factor?
3. List the processes that reduce or eliminate the effects of antinutrients

4.4 Summary

Antivitamins represent a broad class of compounds that counteract the essential effects of vitamins. There are some processes that reduce or eliminate the effects of antinutrients e.g. thermal treatment, chemical detoxification, fermentation and germination

In this unit we continued from the previous unit with antinutrient emphasizing on antivitamins; types of antivitamins, we also considered the processes that reduce or eliminate the effects of antinutrients.

4.5 Glossary

Analogues: Is something that is similar or comparable to something else either in general or in some specific detail

Antinutrients: They are natural or synthetic compounds that interfere with the absorption of nutrients

Antivitamins: They represent a broad class of compounds that counteract the essential effects of vitamins.

By-Products: An incidental or secondary product made in the manufacture or synthesis of something else.

Categorization: The action or process of placing into classes or groups.

Chemical: a distinct compound or substance, especially one which has been artificially prepared or purified

Detoxification: The process of removing toxic substances.

Exposure: The fact of experiencing something or being affected by it because of being in a particular situation or place

Fermentation: A chemical reaction in which sugars are broken down into smaller molecules that can be used in living systems.

Germination: It refers to the process by which an organism grows from a seed or a spore.

Nutrients: They are the substances found in food which drive biological activity, and are essential for the human body.

Organic: Relating to or obtained from living things organic matter

Persistent Organic Pollutants

Preservative: It is a substance or a chemical that is added to products such as food products, beverages, pharmaceutical drugs, paints, biological samples, cosmetics, wood, and many other products to prevent decomposition by microbial growth or by undesirable chemical changes

Vitamin: It is an organic molecule that is an essential micronutrient that an organism needs in small quantities for the proper functioning of its metabolism.

Thermal: Caused by or related to heat or temperature

Toxic: Harmful, causing or capable of causing harm; unhealthful; detrimental to good health; noxious; injurious to physical or mental health

Toxicity: It is the degree to which a chemical substance or a particular mixture of substances can damage an organism

4.6 References/Further Reading

Hangen L. Bennink M.R. Consumption of black beans ad navy beans (Phaseolus vulgaris) reduced azoxymethane induced colon cancer in rats. Nutria. Cancer. 2002, 44, 66-65.

Hedley C.L. Introduction 2001, In: Carbohydrates in Grain Legume Seeds (Ed. C.L. Hedley) CAB International, pp.1-13.

Jansman A.J.M., Longstaff M., Nutritional effects of tannins and vicin/convicine in legume seeds. 1933, in: Proceedings of the 2nd International Workshop on Antinutritional Factors (ANFs) in Legume Seeds. Recent Advances in Anti-nutritional Factors in legume seeds (ed. A.F.B. Van dr Poel, J. Huisman, H.S. Saini). EAAP Publication, Wageningne, the Netherlands, pp. 301-316.

K. O. Soetan and O.E. Oyewol, 2009, The need for adequate processing to reduce the anti-nutritional factors in plants used as human foods and animal feeds. *African Journal of Food Science Vol. 3(9), pp. 223-232, September, 2009. ISSN 1996-0794 C 2007 Academic Journals.*

Muahamad Nadem et al. (2010) An overview of anti-nutritional f actors in creal grains with special reference to wheat –A review Pakistan Journal of Food Sciences (2010). Vol. 20 Issue 1-4, Page(s):54-1.

P. Kiranmayi, Is Bio Active Compounds Inplantsacts as Anti-Nutritional Factors

Panhwar F. 2005). Anti-nutritional factors in oil seeds as aflatoxin in ground nut. Retrieved from www.ChemLin.com

Parul Bora, 2014, Anti-Nutritional Factors in Foods and their Efects Journal of Academia and industrial Research (JAIR) Vol 3 issue 6. 19. Redeen, R.J., Chen, W. & Sharma, B. (2005). Chickpea Breeding and Management. United Kingdom: CABI.

Santosh Khotar Anti-nutritional Factors in Food Legumes and Effects of Processing The Role of Food, Agriculture, Forestry and Fisheries in Human Nutrition. Sarajejvo, 2009, Anti-nutritional Factors in Food Grain Legumes, 1st International Syposium on Sustainable Development, June, 9-10, 40.

Soetan K. and Oyewol O. (2009) The need for adequate processing to reduce the antinutritional factors in plants used as human foods and animal feeds: A review. Africa Journal of Food Science Vol. 3(9), pp. 223-232.

Ugwu, F.M. and Oranye, N.A. (2006). Effects of some processing methods on the toxic components of African breadfruit (Treculia Africana) African Journal of biotechnology 5,2329-2333.

4.7 Possible Answers to Self-Assessment Exercises

1. Antivitamins are substances present in the diet that prevent the assimilation, absorption or metabolism of vitamins. All of them are classified within antinutrients.
2. Coumarins are vitamin k antagonists that produce their anticoagulant effect by interfering with the cyclic interconversion of vitamin k and its 2,3 epoxide(vitamin k epoxide). The anticoagulant effect of coumarins when consumed in excess may lead to bleeding in a situation where there is injury. Foods that have an important content in coumarins are: grapefruit, alfalfa (in the form of sprouts or as an edible wild plant) and capers. People taking anticoagulant medications should take special care not to eat these foods, since their coumarins enhance the effect of the drugs and the risk of bleeding multiplies.
3. The processes that reduce or eliminate the effects of antinutrients are thermal treatment, chemical detoxification, fermentation, and germination.

MODULE 6

UNIT 1 TOXICITY OF PACKAGING MATERIALS

CONTENTS

1.1 Introduction

Packaging is an indispensable element in the food manufacturing process. Nowadays, plastics are used preferentially for packaging foodstuffs. They are capable of retarding and sometimes preventing the detrimental changes that may occur in packed products due to external influences, e.g., oxygen, light, and microorganisms. Plastics are also able to reduce greatly the loss of components, such as water or flavor, from packed material. Therefore, plastic packages extend the shelf-life of many products. Various materials and additives can be used in packaging, as long as they have the desirable functional properties and do not pose health hazards after being in contact with food. Such concerns may occur when some substances migrate from the packaging into the food.

In this unit we will examine toxicity of packaging materials; polymers and their constituents: classification of plastics, monomers, oligomers and other starting substances and additives in polymeric packaging

1.2 Learning Outcomes

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

- discuss ‘additives to polymers’ with some examples
- discuss the classes of plastics
- analyse monomers, oligomers and other starting substances
- evaluate some antioxidants used as additives in polymeric packaging

1.3 Polymers and their Constituents

Plastic materials are the main components of food packages used for dairy products, baked goods, breads, beverages, breakfast cereals, confectionery, pasta, and other miscellaneous food products (Table 1).

Table 1
Polymers commonly used in food packaging applications.

Material	Packaging
Laminated polyethylene-fibreboard-printed polyethylene	Milk carton
Laminated aluminum polyethylene	Chip bag, soup pack
Polystyrene	Yogurt tub, cheese tray, biscuit inner tray
Printed polyethylene	Biscuit, ice cream, bread and chocolate bar wrappers, chip bag, milk shake cup, milk thick shake straw, soy milk tetra pack, pasta, noodles, shredded cheese, outer cheese, carrot slice, coffee, lecithin, green beans, and brown rice packs
Printed fibreboard	Ice cream, biscuit outer, rolled oats, cereal outer, cocoa outer, tea, apricot pie, and jelly outer packs
Polyethylene	Cheese wrapper, cereal contents pack
Polyethylene terephthalate	Ice cream lid, juice container, soft drink bottle
High-density polyethylene	Ice cream tub, milk jug
Low-density polyethylene	Food-freeze and ice bags
Cellophane	Biscuit contents pack, cocoa, and jelly inner packs
Polyvinyl chloride	Lemon squeeze container
Polypropylene	Ketchup bottle

Source: data from Balafas et al. (1999), *Food Chem.*, 65, 279–287.

1.3.1 Classification of Plastics

Plastics can be classified into two

- **Thermoplastic**

Plastics can be classified as thermoplastic or thermosetting. Thermoplastics are materials that can be repeatedly softened by heat and hardened by cooling. Typical of the thermoplastic family are the styrene polymers and copolymers, acrylics, cellulosics, polyethylenes, polypropylenes, vinyls, and nylons.

- **Thermoset**

Thermoset polymers are those that undergo chemical reactions induced by heat, pressure, catalysts, and ultraviolet (UV) light, leading to an infusible state. Typical plastics in the thermosetting family are amines (melamine, benzoguanamine, and urea), most polyesters, alkyds, epoxides, polyurethanes, and phenolics. Thermoset polymers, after crosslinking, drying, curing, and hardening solidify to a three dimensional crosslinked matrix, cannot be melted without destroying their original characteristics. The most common thermoset plastics are epoxy resins, derived from reaction of bisphenol A and epichlorhydrin.

- **Additives to Polymers**

To achieve the desirable functional properties of the finished products, additives have to be incorporated with the polymers. Emulsifiers, surfactants and buffering agents are also used to provide a suitable medium for polymerization.

Monomers or oligomers are not chemically bound to the polymer molecules and can therefore move within the polymer matrix. Consequently, at the interface between packaging material and food they can dissolve in the food product. Monomers are reactive substances with respect to living organisms, and are therefore toxic to some degree.

A lot of concern also focuses on additives from packaging materials ending up in food (e.g., phthalate plasticizers, which are indicated for many serious, chronic health effects).

- **Polyethylene Terephthalate (PET)**

Polyethylene terephthalate (PET) is a copolymer of ethylene glycol with either terephthalic acid or dimethyl terephthalate. PET is used in packaging applications for soft drinks and mineral water, and for the bottles that are collected by curbside or deposit systems. As it does not thermally deform below about 220 C, PET is also used for trays and dishes for microwave and conventional cooking.

PET itself is biologically inert if ingested and is dermally safe during handling. No adverse effects have been observed at exposures anticipated to occur from the use of PET packages.

- **Nylon Resin**

Polyamides, commonly known as 'nylons,' may safely be used to produce articles intended for application in processing, handling, and packaging of food, including for products intended to be cooked directly in their packages.

Nylon microwave and roasting bags were reported to release, at cooking temperatures, volatile compounds, such as Nylon 6,6 cyclic monomer.

1.3.2 Monomers, Oligomers and other starting substances

- **Bisphenol-Type Contaminants**

Bisphenol A (BPA) (Figure 1) is a starting substance utilized in the manufacture of most types of epoxy resins, which are then crosslinked and used to coat food cans. Another application of BPA is in the manufacture of plastic materials, in particular polycarbonates. BPA serves also as an antioxidant or stabilizing material for many types of plastics, e.g., polyvinyl chloride (PVC).

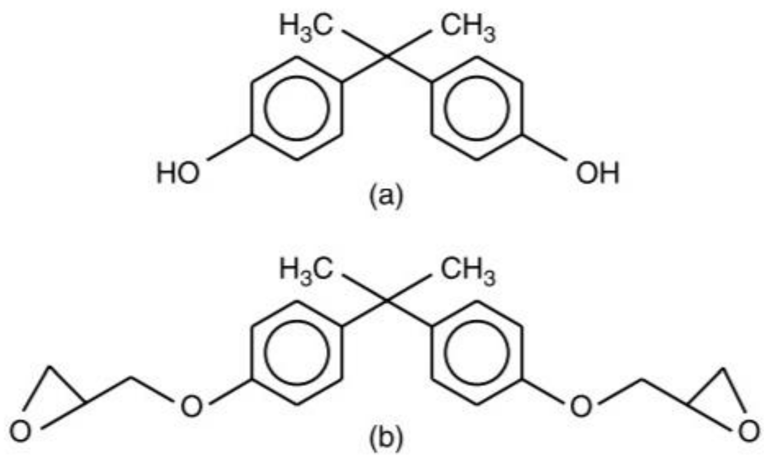


FIGURE 1 Structures of (a) bisphenol A, (b) bisphenol A diglycidyl ether.

All the bisphenol-type compounds mentioned have the potential to migrate into the packaged food. Migration of BPA can occur from can coatings into food or food simulants. BPA migration has been identified in canned commodities, including vegetables, fish in aqueous media, and meat products, and from cans containing coffee and caffeine. PVC stretch films used for food packaging may also be a source of BPA. The monomer can be leached when canned food is heated at typical can processing temperatures.

- **Isocyanates**

Isocyanates are used in polyurethane polymers and adhesives. In production of multilayer plastic materials, it is common to apply reactive adhesive mixtures containing aromatic isocyanate monomers. However, in cases of incomplete curing, primary aromatic amines (PAAs) may be produced from residues of the aromatic isocyanates and water. PAAs can be transferred from packaging into food. Some PPAs, including 2,4-diaminotoluene and 4,40 -methylenedianiline, are classified as ‘‘possibly carcinogenic to humans’’ by the International Agency for Research on Cancer (IARC).

- **Styrene**

Styrene is a commercially important monomer that is used extensively in the manufacture of polystyrene resins and in co-polymers with acrylonitrile and 1,3-butadiene (reinforced plastics). Exposure to styrene occurs due to intake of food that has been in contact with styrene-containing polymers. IARC has determined that styrene is possibly carcinogenic to humans.

- **Vinyl Chloride**

Vinyl chloride monomer (VCM) is the main substrate for the manufacture of polymers used as packaging materials for food. Since VCM is considered by IARC to be a human carcinogen, monomer levels in PVC food packaging materials are strictly controlled. To ensure a safe product, the residual content of VCM in the finished material or article is limited to one mg per kg in the final product.

1.3.3 Additives in Polymeric Packaging

Antioxidants, Light Stabilizers and Thermal Stabilizers

Plastics generally age rapidly and undergo polymer degradation when exposed to UV light and in the presence of oxygen. The rate of oxidation is decreased by adding stabilizing additives, such as antioxidants or light stabilizers.

Commonly used antioxidants include:

- mixtures of the isomers 3-tert-butyl-4-hydroxyanisole and 2-tert-butyl4-hydroxyanisole (BHA)
- 2,6-di-tert-butyl-4-methyl-phenol (BHT)
- 2-(20 -hydroxy-50 methylphenyl)benzotriazole (Tinuvin P)
- 2-(5-chloro-2H-benzotriazole-2-yl)-6-(1,1-dimethylethyl)-4-methylphenol(Tinuvin 326)
- bis(2,2,6,6-tetramethyl-4-piperydyl)sebacate (Tinuvin 770 DF)
- 2-[2-hydroxy-3,5-bis(1-methyl-1-phenyl)phenyl]benzotriazole (Tinuvin 234)
- 2-hydroxy-4-n-octyloxybenzophenone (Chimasorb 81)
- octadecyl-3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate (Irganox 1076)
- 1,3,5-trimethyl-2,4,6-tris(3,5-di-tert-butyl-4-hydroxyphenyl)propionate (Irganox 1330)
- pentaerythrityl-tetrakis-3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate (Irganox 1010)
- tris-(2,4-di-tert-butylphenyl)phosphite (Irgafos 168)
- tetrakis(2,4-di-tert-butylphenyl)-4,4’-biphenylene diphosphonite (Irgafos P-EPQ)

Some of these antioxidants appear in the list of additives that may be used in the manufacture of plastic materials intended to come into contact with food.

- **Plasticizers**

Plasticizers are used in the polymer industry to improve flexibility, workability, and general handling properties. Dibutyl sebacate and phthalates, such as dibutyl phthalate, diethyl phthalate, dicyclohexyl phthalate, butylbenzyl phthalate, and diphenyl-2-ethylhexyl phosphate, serve widely as plasticizers in vinylidene chloride copolymers, nitrocellulose-coated regenerated cellulose film, and cellulose acetate.

Butyl stearate, acetyltributyl citrate, alkyl sebacates, and adipates are typical low-toxicity plasticizers and are commonly used.

- **Lubricants and Slip Additives**

While plasticizers change the physical properties of a polymer, lubricants are added to change the processing properties of the material. Lubricants are widely used in thermoplastic polymers to increase the overall rate of processing or to improve surface release properties during extrusion, injection, molding or compression molding.

Slip additives act at the surface of a polymer film or article to reduce the friction between it and another surface.

- **Nonylphenol**

Alkylphenols, e.g., p-nonyl-phenol (NP), serve widely as antioxidants and surfactants for plastics such as PVC and polystyrene. NP, like BPA and some phthalic acid esters, belongs to the group of anthropogenic endocrine disruptors.

Table 2
Commonly used lubricants.

Lubricant	Examples of use
Saturated hydrocarbons	Paraffin waxes, microcrystalline wax, earth wax, polyethylene waxes, oxidized polyethylene waxes
Fatty acids	Stearic acid
Metallic soaps	Zinc and calcium stearate
Fatty acid esters	The butyl stearate, octyl stearate, fatty acid glyceryl esters
Fatty acid amides	Stearamide, erucamide, ethylene bisstearamide (EBS), ethylene bisoleamide (EBO)

Source: data from Wang and Buzanowski (2000), *J. Chrom. A*., 891, 313–324.

Self-Assessment Exercises

1. Analyse the classes of plastics.
2. Discuss additives to polymers.
3. Discuss the functions of plasticizers in polymers

1.4 Summary

Food packaging is of high societal value because it conserves and protects food, making food transportable and conveys information to customers. It is also relevant for marketing, which is off economic significance. Food and beverages can be very aggressive products and may interact strongly with materials that they touch hence materials used in packaging must be able to preserve and protect its content, resist any chemical reactions, and withstand the handling and processing conditions.

In this unit we examined toxicity of packaging materials; polymers and their constituents: classification of plastics, monomers, oligomers and other starting substances and additives in polymeric packaging

1.5 References/Further Reading

Toxins in Food edited by Waldemar M. Da¸browski & Zdzislaw E. Sikorski retrieved from https://zavo.info/download/compresspdf

1.6 Possible Answers to Self-Assessment Exercises

1. Analysis of classes of plastics: Plastics are classified into two; thermoplastic and thermoset

Thermoplastic - These are materials that can be repeatedly softened by heat and hardened by cooling. Typical of the thermoplastic family are the styrene polymers and copolymers, acrylics, cellulosics, polyethylenes, polypropylenes, vinyls, and nylons.

Thermoset polymers are those that undergo chemical reactions induced by heat, pressure, catalysts, and ultraviolet (UV) light, leading to an infusible state. Typical plastics in the thermosetting family are amines (melamine, benzoguanamine, and urea), most polyesters, alkyds, epoxides, polyurethanes, and phenolics. Thermoset polymers, after crosslinking, drying, curing, and hardening solidify to a three dimensional crosslinked matrix, cannot be melted without destroying their original characteristics. The most common thermoset plastics are epoxy resins, derived from reaction of bisphenol A and epichlorhydrin.

2. Additives to polymers: To achieve the desirable functional properties of the finished products, additives have to be incorporated with the polymers. Emulsifiers, surfactants and buffering agents are also used to provide a suitable medium for polymerization.

Monomers or oligomers are not chemically bound to the polymer molecules and can therefore move within the polymer matrix. Consequently, at the interface between packaging material and food they can dissolve in the food product. Monomers are reactive substances with respect to living organisms, and are therefore toxic to some degree.

A lot of concern also focuses on additives from packaging materials ending up in food (e.g., phthalate plasticizers, which are indicated for many serious, chronic health effects).

3. Functions of plasticizers in polymers: Plasticizers are used in the polymer industry to improve flexibility, workability, and general handling properties of polymers. Dibutyl sebacate and phthalates, such as dibutyl phthalate, diethyl phthalate, dicyclohexyl phthalate, butylbenzyl phthalate, and diphenyl-2-ethylhexyl phosphate, serve widely as plasticizers in vinylidene chloride copolymers, nitrocellulose-coated regenerated cellulose film, and cellulose acetate.

Butyl stearate, acetyltributyl citrate, alkyl sebacates, and adipates are typical low-toxicity plasticizers and are commonly used.

UNIT 2 FOOD PROCESS CONTAMINANTS / INDUSTRIAL EFFLUENTS / NOISE POLLUTION

CONTENTS

2.1 Introduction

The processing industries are a part of our environment and are often major generators of waste. Since the existing environment within which they operate is the only one we have, and share by the consumers and operators of the sectors of the economy, there is the need therefore, to ensure the preservation of the environment in as natural and ecologically balance a state as possible for the use of all.

The food industries should be aware of the content of the waste they generate with the view of making them environment friendly.

In this unit we shall examine food process contaminants / industrial effluents / noise pollution

2.2 Learning Outcomes

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

- discuss the following
  a) polycyclic aromatic hydrocarbons (pah)
  b) maillard reaction products
  c) amino acid pyrolysates
  d) n-nitrosamines
  e) food irradiationdiscuss industrial wastewater pollutants
- discuss the characteristics of noise
- discuss the types of noise sources

2.3 Food Process Contaminants

The development of food processing technology—which includes frying, toasting, roasting, evaporation, smoking, sterilization, pasteurization, irradiation, pickling, freezing, and canning—expanded the potential of food supplies greatly in the modern era. For example, smoke treatment made a year-round supply of fish possible and canned foods could be sent anyplace in the world.

However, the chemical changes in food components, including amino acids, proteins, sugars, carbohydrates, vitamins, and lipids, caused by high-heat treatment have raised questions about the usual consequence of reducing nutritive values and even the formation of some toxic chemicals such as polycyclic aromatic hydrocarbons (PAHs), amino acid or protein pyrolysates, and N-nitrosamines. Among the many reactions occurring in processed foods, the Maillard Reaction plays the most important role in the formation of various chemicals (including toxic ones).

1) Polycyclic Aromatic Hydrocarbons (PAH)

Polycyclic aromatic hydrocarbons occur widely in the environment. The typical PAHs are shown in Figure 1. One of the most abundant food sources of PAHs is vegetable oil.

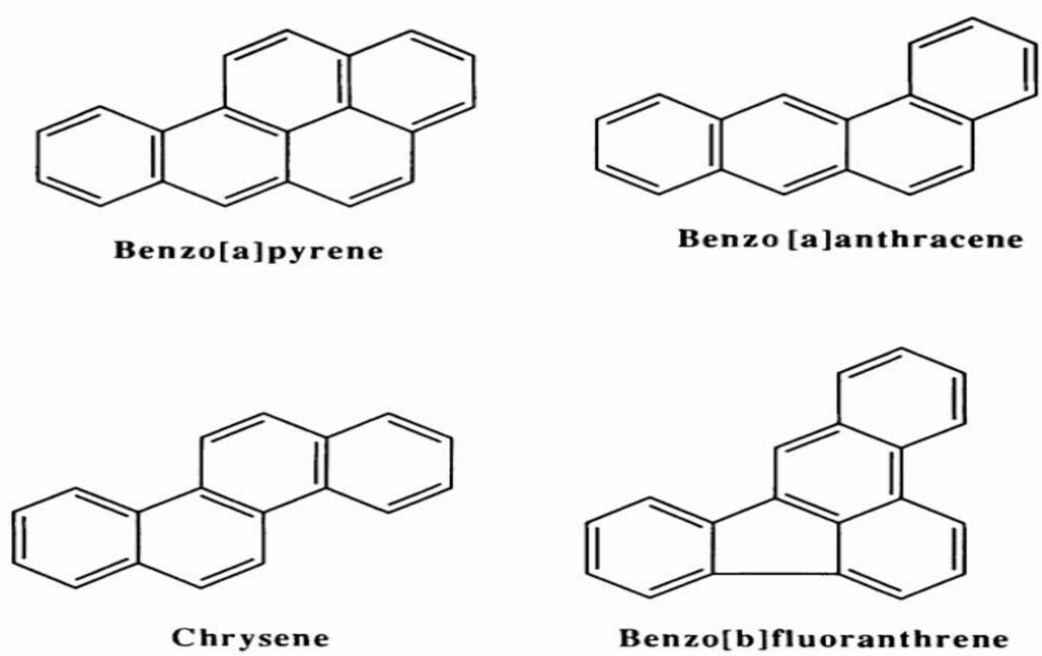


Figure I Polycyclic aromatic hydrocarbons.

Benzyl(o)pyrene

The most commonly known carcinogenic PAH is benzo[a]pyrene (BP), which is widely distributed in various foods.

Toxicity - For over 200 years, carcinogenic effects have been ascribed to PAHs. In 1775, Percival Pott, an English physician, made the association between the high incidence of scrotal cancer in chimney sweeps and their continual contact with chimney soot. The research on the toxicity of PAHs, however, progressed somewhat slowly. In 1932, benzo[a]pyrene (BP) was isolated from coal tar and found to be highly carcinogenic in experimental animals.

2) Maillard Reaction Products

The summary of the Maillard reaction is shown in Figure 2. Many chemicals form from this reaction in addition to the brown pigments and polymers. Because of the large variety of constituents, a mixture obtained from a Maillard reaction shows many different chemical and biological properties: brown colour, characteristic roasted or smoky odours, pro- and anti-oxidants, and mutagens and carcinogens, or perhaps anti-mutagens and anti-carcinogens.

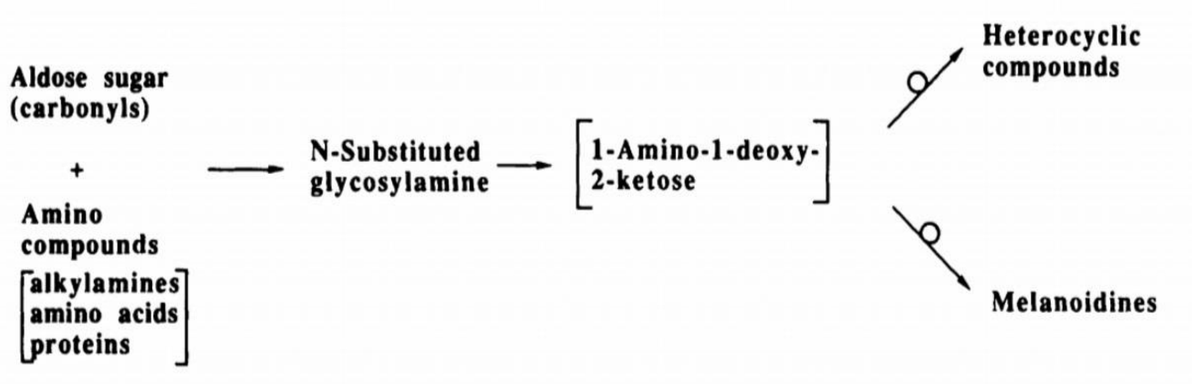


Figure 2 Summary of the Maillard reaction.

3) Amino acid pyrolysates

In the late 1970s, mutagenicity of pyrolysates obtained from various foods was reported that could not be accounted for by PAHs formed on the charred surface of certain foods such as broiled fish and beef. The mutagenic principles of the tryptophan pyrolysates were later identified as nitrogen-containing heterocyclic compounds. A group of polycyclic aromatic amines is produced primarily during the cooking of protein-rich foods. Their structures are shown in Figure 3. The early work on the isolation and production of these substances was based on their mutagenicity.

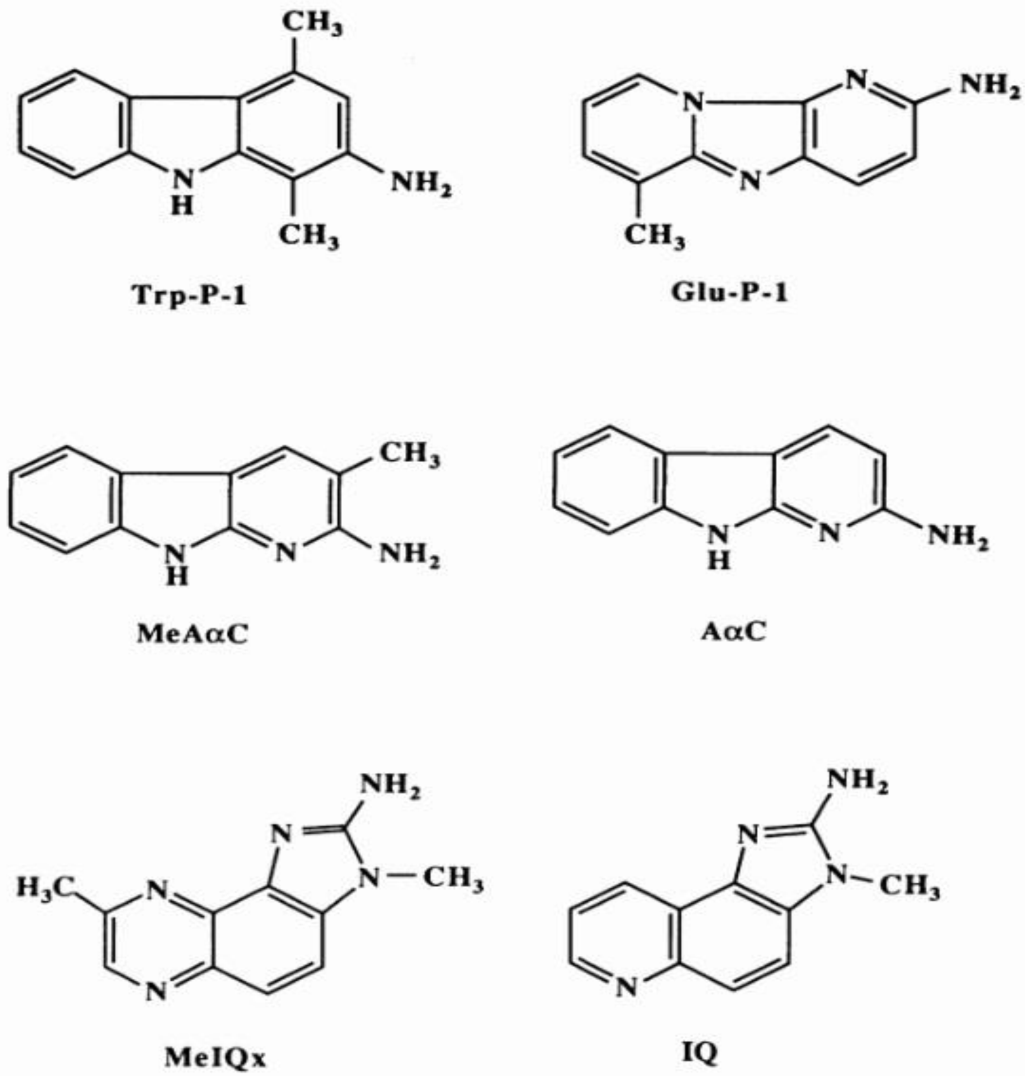


Figure 3 Mutagenic heterocyclic amines.

4) N-Nitrosamines

N-nitrosamines have been an issue due to nitrite which was added to prevent the growth of clostridium botulinium in processed meat.

5) Food Irradiation

The use of ionizing radiation to preserve food falls into this category.

Gamma radiation is most often used for food irradiation. Gamma rays are a form of electromagnetic radiation produced by such radioactive elements as Cobalt-60 and Cesium-137. Such sources emit radiation with energies of up to 10 million electron volts (MeV). This is sufficient to penetrate deep into foods, but is far below the range required to produce radioactivity in the target material. Since there is no direct contact between the source and the target, there is no mechanism that can produce radioactivity in irradiated foods.

Ionizing radiation can sterilize foods, control microbial spoilage, control insect infestations, and inhibit undesired sprouting. Food irradiation has the potential to substantially reduce postharvest applications of pesticides to prevent spoilage due to insects and fungi. Irradiation can be used to destroy Salmonella in cases where heat treatment is not possible, for example, in frozen chicken.

Despite the potential of food irradiation as a preserving technique, it is widely misunderstood and controversial. Some opposition arises from apparent confusion between "irradiated" and "radioactive". Gamma irradiation of foods is in some ways analogous to sterilization of medical equipment with ultraviolet light. Both of these processes can kill a wide range of microorganisms by radiation.

Some other critics have raised questions about the toxicity of chemicals that may be produced during irradiation. The energies used are sufficient to produce free radicals, which can combine with each other or form new bonds to other compounds that may be present. However, it is important to remember that heat treatments commonly used in food processing are likely to produce a higher degree of chemical modification than is irradiation.

Self-Assessment Exercises 1

1. What are food process contaminants?
2. What is Maillard reaction?

2.4 Industrial Wastewater Pollutants

Increase in Industrialization has led to increase in the production of industrial waste. . These industrial wastes cause major environmental havoc by polluting the water, air and soil. The quality and quantity of wastewater generated depends on the type of industry: it can contain non-biodegradable waste such as heavy metals, pesticides, plastic etc. and biodegradable compounds such as paper, leather, wool etc. Industrial wastewater can be toxic, reactive, carcinogenic or ignitable. Therefore, without proper treatment and management strategies, the discharging of the waste into water bodies can pose dreadful environmental and health effects.

2.4.1 Sources of Industrial Wastewater

Several waterborne pathogens proliferate in wastewater and produce toxins, affecting the earth's ecosystem and human health. The toxins in industrial wastewater cause acute poisoning, immune system suppression and reproductive failure. According to the WHO, around 80% of diseases are waterborne. To address the environmental and health issues created by industrial wastewater, it is absolutely necessary to obliterate its toxicity by adequate treatment with physical, chemical and biological means so that it can be recycled for water conservation.

2.4.2 Types

In general, wastewater has been categorized into two broad types: sewage wastewater and non-sewage wastewater. Sewage wastewater includes discharge from domestic activities. The wastewater produced from places like houses, schools, hospitals, hotels, restaurants, public toilets etc. containing body wastes (urine and faeces) comes under sewage wastewater. All the other types of wastewater produced from commercial activities such as that generated from factories and industrial plants are termed non-sewage wastewater. The non-sewage wastewater also includes storm water and rainwater generated after rainfall or flood events. Day-to-day human activities are majorly water dependent which makes wastewater management and treatment very important.

2.4.3 Possible Pollutants from Industrial Wastewater

Water with dissolved and suspended substances discharged from various industrial processes, such as the water released during manufacturing, cleaning and other commercial activities, is termed industrial wastewater. The nature of the contaminants present in industrial wastewater depends on the type of the factory and the industry. Examples of industries that produce wastewater are the mining industry, steel/iron production plants, industrial laundries, power plants, oil and gas fracking plants, metal finishers and the food/beverage industry. The various contaminants commonly found in industrial water outlets are chemicals, heavy metals, oils, pesticides, silt, pharmaceuticals and other industrial by-products. In general, it is difficult to treat industrial wastewater, as individual examination of the set-ups and specific treatment plants are required on an industry-based level. Therefore, to deal with this, on-site filter presses are installed to treat the effluent wastewater.

Self-Assessment Exercises 2

1. Discuss industrial wastewater pollutants.
2. Analyse the contaminants commonly found in industrial water outlets

2.5 Noise Pollution

Noise is playing an ever-increasing role in our lives and seems a regrettable but ultimately avoidable corollary of current technology. The trend toward the use of more automated equipment, sports and pleasure craft, high-wattage stereo, larger construction machinery, and the increasing numbers of ground vehicles and aircraft has created a gradual acceptance of noise as a natural by-product of progress.

Noise pollution is thus another environmental pollutant to be formally recognized as a genuine threat to human health and the quality of life. The fundamental insight we have gained is that noise may be considered a contaminant of the atmosphere just as definitely as a particulate or a gaseous contaminant. There is evidence that, at a minimum, noise can impair efficiency, adversely affect health, and increase accident rates. At sufficiently high levels, noise can damage hearing immediately, and even at lower levels, there may be a progressive impairment of hearing.

This unit is descriptive. It deals with the sources, characteristics, and effects of noise, describes methods for the measurement and analysis of noise, and lists some of the guidelines that are used to control the problem.

- **Characteristics of Noise**

Noise levels in general have increased over the years and some authorities hold that average noise levels in cities have increased at about 1 dB per year for the last 30 yr. The sound pressure level represents the magnitude of a noise source and is one of the characteristics that can assess whether a given noise is considered to be annoying. There are other characteristics, both intrinsic to the noise and its context, that dictate whether people will consider it to be annoying:

1. Frequency content or bandwidth
2. Duration
3. Presence of pure tones or transients
4. Intermittency
5. Time of day
6. Location (or activity)

- **Sources**

Basically, noise sources can be grouped into three types: transportation, industrial, and residential.

Transportation Sources - Transportation sources of noise are comprised principally of automotive and aircraft noises; motorcycles, scooters, and snowmobiles should also be considered. A main contributor to transportation noise is automotive traffic.

Industry - Some industrial operations and equipment are significant noise sources. Principal examples are machinery or machine tools, pneumatic equipment, high-speed rotating or stamping operations, and duct, fan, and blower systems. Typical noise levels for operating personnel may be quite high.

Community exposure to such noises would, of course, depend on the proximity to the noise sources, and ambient noise levels in residential areas could be affected.

Residential - Residential sources, both indoor and outdoor, may not seem so significant at first. However, when one considers air conditioners, lawn mowers, power saws, dishwashers, kitchen and laundry appliances, television, stereos, pets, and children, the overall severity of these sources cannot be ignored. Furthermore, the simple increase in the numbers of tools, cars, gadgets, and appliances used by modern industrial societies can create a substantial noise burden.

- **Effect**

Effects of noise include physiological and annoyance types.

Physiological effect - there is evidence indicating that exposure to noise of sufficient intensity and duration can permanently damage the inner ear, with resulting permanent hearing loss. Loss of sleep from noise can increase tension and irritability; even during sleep, noise can lessen or diminish the relaxation that the body derives from sleep.

Annoyance effect - In the annoyance category, noise can interfere with speech communication and the perception of other auditory signals; the performance of complicated tasks can be affected by noise. Noise can adversely affect mood, disturb relaxation, and reduce the opportunity for privacy. In all of the above ways, noise can detract from the enjoyment of our environment and can affect the quality of human life.

- **Control**

There are essentially three approaches to noise reduction and control.

- **Source control**

Source control can be achieved by careful consideration of noise control during the design of new products.

- **Rerouting or Relocating noise source**

When the desired amount of noise reduction cannot always be achieved by good acoustic design at the noise source, the next best solution is the modification or alteration of the noise path between the source and the receiver. Rerouting or relocating noise sources is an example of path modification and is best applied in the planning stage of highways and airports.

- **Shielding**

Another method of path modification is to interpose barriers between the source and receiver. Such a “shielding” is useful in attenuating highway noise levels imposed on nearby areas.

Self-Assessment Exercises 3

1. Discuss the characteristics of noise.
2. Discuss sources of noise.
3. Analyse the effects of noise.

2.6 Summary

The food processing sector is important at the national level, given the number of companies and industrial production. This sector is very active and provides essential services in the supply of various consumer products in major urban centers. However, the price to pay o meet the population needs is high, since it results in environmental pollution characterized by the uncontrolled discharge of food processing effluents into the terrestrial and aquatic ecosystems. These effluents come from a fairly diversified food processing sector such as brewing, dairy and sugar industries, distilleries, slaughterhouses, oil mills and sweet manufacturing.

In this unit we shall examine food process contaminants / industrial effluents / noise pollution; various industrial pollutants, industrial wastewater pollutants, characteristics of noise, types of noise sources, approaches to noise reduction and control etc.

2.7 References/Further Reading

Advanced Air and Noise Pollution Control: Volume 2 (Handbook of environmental engineering) edited by Lawrence K. Wang, Norman C. Pereira & Yung-Tse Hung retrieved from https://p3vpiybkaf.pdcdn1.top/dl2.php?id=184267182&h=664f916f5a6fa5897a0fd4bc5cc82373&u=cache&ext=pdf&n=Advanced%20air%20and%20noise%20pollution%20control%20volume%202%20handbook%20of%20environmental%20engineering

F. Beltran Sevilla, Toxicants formed during food processing retrieved from https://lms.su.edu.pk/download?filename=1606997493-l-14-a.pdf&lesson=51239

https://www.epa.gov/sites/default/files/2016-09/documents/n-nitrosodimethylamine.pdf

Jebin Ahmed, Abhijeet Thakur and Arun Goyal chapter 1 industrial wastewater and its toxic effects, retrieved from https://pubs.rsc.org/en/content/chapterhtml/2021/bk9781839162794-00001?isbn=978-1-83916-279-4&sercode=bk

2.8 Possible Answers to Self-Assessment Exercises

Self-Assessment Exercises 1

1. Food processing contaminiants refer to chemicals formed unintentionally during food manufacturing, cooking (including home cooking), packaging and other processing activities. The best known processes that cause substantial change in food include cooking fermentation and acid hydrolysis.
2. The Maillard reaction is an organic chemical reaction in which reducing sugars react with amino acids to form a complex mixture of compounds. This reaction is responsible for the characteristic flavour and aroma of browned food.

Self-Assessment Exercises 2

1. Industrial wastewater pollutants: Increase in Industrialization has led to increase in the production of industrial waste. . These industrial wastes cause major environmental havoc by polluting the water, air and soil. The quality and quantity of wastewater generated depends on the type of industry: it can contain non-biodegradable waste such as heavy metals, pesticides, plastic etc. and biodegradable compounds such as paper, leather, wool etc. Industrial wastewater can be toxic, reactive, carcinogenic or ignitable. Therefore, without proper treatment and management strategies, the discharging of the waste into water bodies can pose dreadful environmental and health effects.

2. Analysis of the contaminants commonly found in industrial water outlets

Water with dissolved and suspended substances discharged from various industrial processes, such as the water released during manufacturing, cleaning and other commercial activities, is termed industrial wastewater. The nature of the contaminants present in industrial wastewater depends on the type of the factory and the industry. Examples of industries that produce wastewater are the mining industry, steel/iron production plants, industrial laundries, power plants, oil and gas cracking plants, metal finishers and the food/beverage industry. The various contaminants commonly found in industrial water outlets are chemicals, heavy metals, oils, pesticides, silt, pharmaceuticals and other industrial by-products. In general, it is difficult to treat industrial wastewater, as individual examination of the set-ups and specific treatment plants are required on an industry-based level. Therefore, to deal with this, on-site filter presses are installed to treat the effluent wastewater.

Self-Assessment Exercises 3

1. Characteristics of noise: Noise levels in general have increased over the years and some authorities hold that average noise levels in cities have increased at about 1 dB per year for the last 30 years. The sound pressure level represents the magnitude of a noise source and is one of the characteristics that can assess whether a given noise is considered to be annoying. There are other characteristics, both intrinsic to the noise and its context, that dictate whether people will consider it to be annoying or not. The characteristics of noise include its frequency content or bandwidth, duration, presence of pure tones or transients, intermittency, time of day and location (or activity).

2. Sources of noise: Basically, noise sources can be grouped into three types: transportation, industrial, and residential.

i. Transportation Sources **-** Transportation sources of noise are comprised principally of automotive and aircraft noises; motorcycles, scooters, and snowmobiles should also be considered. A main contributor to transportation noise is automotive traffic.
ii. Industrrial Sources **-** Some industrial operations and equipment are significant noise sources. Principal examples are machinery or machine tools, pneumatic equipment, high-speed rotating or stamping operations, and duct, fan, and blower systems. Typical noise levels for operating personnel may be quite high. Community exposure to such noise would, of course, depend on the proximity to the noise sources, and ambient noise levels in residential areas could be affected.
iii. Residential sources, both indoor and outdoor, may not seem so significant at first. However, when one considers air conditioners, lawn mowers, power saws, dishwashers, kitchen and laundry appliances, television, stereos, pets, and children, the overall severity

of these sources cannot be ignored. Furthermore, the simple increase in the numbers of tools, cars, gadgets, and appliances used by modern industrial societies can create a substantial noise burden.

3. Analysis of the effects of noise: Effects of noise include physiological and annoyance types. Physiological effect - there is evidence indicating that exposure to noise of sufficient intensity and duration can permanently damage the inner ear, with resulting permanent hearing loss. Loss of sleep from noise can increase tension and irritability; even during sleep, noise can lessen or diminish the relaxation that the body derives from sleep.

Annoyance effect - In the annoyance category, noise can interfere with speech communication and the perception of other auditory signals; the performance of complicated tasks can be affected by noise. Noise can adversely affect mood, disturb relaxation, and reduce the opportunity for privacy. In all of the above ways, noise can detract from the enjoyment of our environment and can affect the quality of human life.

UNIT 3 AIR POLLUTION

CONTENTS

3.1 Introduction

Air pollution is the contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere.

In this unit we shall examine Air pollution; urban pollutants: incineration-generated pollutants, pollution by motor vehicles, pollution by incinerators and indoor air pollution

3.2 Learning Outcomes

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

- discuss the incineration-generated pollutants
- discuss the pollution by motor vehicles
- discuss pollution by incinerators
- discuss the indoor air pollution

3.3 Urban Pollutants

Although the problems of air pollution have been recognized for many decades, they were once considered to be only of local significance, restricted to industrial urban areas. With the current recognition of the destruction of stratospheric ozone, the greenhouse effect, worldwide forest destruction, and the acidification of lakes and coastal waters, air pollution assumes global significance.

- Sources of Urban Air Pollution

The sources of urban air pollution are

- power generation
- transportation
- industry, manufacturing, and processing
- residential heating
- waste incineration

Except for waste incineration, all of these pollution sources depend on fossil fuel and, to a lesser degree, on fuel from renewable resources such as plant material. Therefore, all of them produce essentially the same pollutants, although the quantity of each substance may vary from source to source.

3.3.1 Incineration- generated pollutants

The principal incineration-generated pollutants are carbon monoxide (CO), sulfur dioxide (SO2), a mixture of nitrogen oxides (NOx), a mixture of hydrocarbons, referred to as volatile organic compounds (VOCs), suspended particulate matter (SPM) of varying sizes, and metals, mostly bound to particles. Waste incineration, in addition, produces some chlorinated dioxins and furans that are formed on combustion of chlorine-containing organic substances.

- **Carbon Monoxide (CO)**

Most global emissions of this gas (60–90%) originate from natural sources, such as decomposition of organic matter and volcanic activities. The anthropogenic origin is primarily due to incomplete combustion of fossil fuel, particularly in internal combustion engines. Thus, motor vehicles are the main culprits. Carbon monoxide is a colorless, odorless, highly toxic gas. Its toxicity is due to its ability to displace haemoglobin bound oxygen.

A lethal intoxication with CO can occur only in an enclosed space. In open spaces the effect of carbon monoxide is mitigated by dispersion.

- **Sulfur Dioxide (SO_2)**

Sulfur dioxide is a colourless gas of a strong suffocating odour, intensely irritating to eyes and to the upper respiratory tract. . The natural sources of sulfur dioxide are volcanoes and decaying organic matter. In addition, dimethyl sulfide, which comes from the oceans, is converted in the atmosphere to sulfur dioxide. . Exposure to sulfur dioxide causes bronchial constriction and increases air-flow resistance. Thus, it is particularly dangerous to people with respiratory problems.

- **Nitrogen Oxides (NOx)**

Nitric oxide (NO) is formed by natural processes such as lightning and microbial digestion of organic matter. Microbial digestion first produces nitrous oxide (N_2O), which is then oxidized to NO. Anthropogenic formation of nitrogen oxides results from high-temperature combustion, whereby nitrogen in the air combines with oxygen. Nitric oxide is readily oxidized in the atmosphere to NO_2, and the mixture of both gases is referred to as NOx. The total amount of NOx formed during combustion and the ratio of NO to NO_2 depend on the fuel-to-air ratio and on the temperature of combustion.

Nitrogen dioxide is a reddish brown, irritating, and extremely toxic gas. When inhaled, it causes inflammation of the lungs, which after a delay of several days may develop into edema (swelling of the tissue) A short exposure to 100 ppm is dangerous and 200 ppm is lethal.

- **Photochemical Smog**

The mixture of ozone, PAN (Peroxyacetilnitrates), and other by-products such as aldehydes and ketones creates a haze that is referred to as photochemical smog.

Ozone is a respiratory toxin. Because it has low water solubility, it penetrates deep into bronchioles and alveoli. Acute exposure to ozone, which is mostly an occupational hazard, damages the respiratory tissue and causes edema, which may be fatal. Sublethal exposure increases sensitivity to bronchoconstrictive agents and to infections. Chronic exposure to ozone may lead to bronchitis and emphysema. In addition, photochemical smog (i.e., ozone, PAN, and other by-products) is an irritant of the mucous membranes, eyes, and skin.

- **Volatile Organic Compounds**

VOCs originate from both anthropogenic and natural sources. The natural sources are vegetation, microbial decomposition, forest fires, and natural gas. Anthropogenic emission results from incomplete combustion of fossil fuels and from evaporation of liquid fuels and solvents during storage, refining, and handling. All culminating to the formation of PAHs in the air. . At least 26 airborne PAHs, some of them potential carcinogens and mutagens, have been identified.

- **Exposure at Work and via the Food Chain**

People in certain occupations, such as coke-oven workers and coal tar pitch workers, are at high risk. Their exposure may exceed that of the general population by a factor of 30,000 or more. In addition, urban generated particles loaded with PAHs settle on land or water, and the carcinogens are likely to enter the food chain.

- **Benzene and Ethylene**

Benzene is a human bone marrow poison and a carcinogen implicated as a cause of myelocytic and acute nonlymphocytic leukemia. Ethylene is one of the major products of automobile exhaust, but it may also be formed by other combustion processes. It contributes heavily to photochemical oxidants.

- **Airborne Particles**

Particles are referred to as suspended particular matter (SPM). They may be divided into suspended solids and liquid droplets. They both have effects on respiratory and systemic toxicity differ. The natural sources of airborne particles are dust, sea spray, forest fires, and volcanoes.

- **Metal Pollutants**

Among the metal pollutants, lead, mercury, and beryllium are of special interest because of their toxicity.

— Lead may cause neurodevelopmental effects in children even at low levels. Other effects include cardiovascular, renal, gastrointestinal, haematological and reproductive effects.

— Mercury exposure can harm the brain, heart, kidneys, lungs and immune system of people of all ages.

— Beryllium: The major toxic effects of beryllium are pneumonitis (a disease characterized by lung inflammation) and berylliosis (a chronic pulmonary disease).

- **Nonmetal Pollutants**

Fluorides and asbestos are nonmetal pollutants. Fluorine is a by-product of coal combustion. It is released, entirely in the gas phase, in relatively large quantities. Being a reactive element, it combines readily with other atoms and molecules to form fluorides, which are respiratory irritants.

Airborne asbestos originates from industrial use and from the demolition of old buildings containing asbestos. Its health effects are mostly limited to asbestos workers and to workers who are incidentally exposed to asbestos while performing their duties.

3.3.2 Pollution by Motor Vehicles

- **Gaseous and Vapour Pollution**

In many cities around the world motor vehicles are the principal source of NOx emissions. . However, the pollution-control devices perform satisfactorily only when properly maintained. Poor maintenance, tampering, and insufficient monitoring and inspection make the attainment of air quality standards problematic.

- **Rubber**

Rubber particles from tires contribute to air pollution and to water pollution as they are washed out with storm water into the watershed.

3.3.3 Pollution by Incinerators

Another concern is the emission of airborne toxins by municipal and toxic waste incinerators. With the growing shortage of waste disposal sites and the increase in the cost of disposal, municipalities in and around the industrialized world are tending to dispose of municipal waste by incineration and to use the heat produced for energy generation.

- **Facility Effectiveness**

Although modern incinerators may meet the air quality standards for conventional pollutants, there is concern for incineration of chlorine-containing compounds, such as bleached paper and poly(vinyl chloride) plastics, produces toxic (and until recently, unregulated) dioxins and furans.

- **Chemical Waste**

Waste incinerators contribute significantly to air pollution by emitting toxic metals such as mercury, lead, zinc, cadmium, tin and antimony. Reports have indicated that people living in close vicinity to toxic waste incinerators had a greater prevalence of coughing, phlegm, wheezing, sore throat, eye irritation, empysema, sinus trouble and neurological diseases than those living some distance from the incinerators.

3.3.4 Indoor Air Pollution

The main source of indoor air pollution in the developing countries is combustion of coal or biomass (wood, dung, agricultural waste, etc.) for heating and cooking in primitive, poorly vented stoves. The pollutants in that case are respirable particles coated with PAHs, nitrogen dioxide, sulfur dioxide, carbon monoxide, and a variety of VOCs.

Most of these pollutants are either irritants of tender tissues, respiratory and cardiovascular toxins, or both. In addition, some PAHs are carcinogens and mutagens mostly affecting the respiratory system. Sometimes, especially in rural houses, the concentration of certain indoor pollutants exceeds the WHO guidelines. Because women in the agricultural communities spend most of their time indoors performing household chores, exposure to fumes of biomass fuels might be the single most important health hazard for women.

Self-Assessment Exercise

1. Analyse sources of urban air pollution.
2. Discuss pollution by motor vehicles
3. Discuss pollution by incinerators
4. Discuss indoor air pollution

3.4 Summary

The gaseous criteria air pollutants of primary concern in urban settings include sulphur dioxide, nitrogen dioxide, and carbon monoxide; these are emitted directly into the air from incineration, automobile and other combustion sources.

In this unit we examined Air pollution; urban pollutants: incineration-generated pollutants, pollution by motor vehicles, pollution by incinerators and indoor air pollution

3.5 References/Further Reading

Environmental Toxicology, Third Edition, Sigmund F. Zakrzewski ,Oxford University Press retrieved from http://pustaka.unp.ac.id/file/abstrak_kki/EBOOKS/Environmental%20Toxicology%203rd%20edition.pdf

www.epa.gov/lead

www.epa.gov/mercury/about

3.6 Possible Answers to Self-Assessment Exercises

1. Analysis of sources of urban air pollution: Although the problems of air pollution have been recognized for many decades, they were once considered to be only of local significance, restricted to industrial urban areas. With the current recognition of the destruction of stratospheric ozone, the greenhouse effect, worldwide forest destruction, and the acidification of lakes and coastal waters, air pollution assumes global significance. The sources of urban air

pollution are power generation, transportation, industry, manufacturing, processing, residential heating and waste incineration

Except for waste incineration, all of these pollution sources depend on fossil fuel and, to a lesser degree, on fuel from renewable resources such as plant material. Therefore, all of them produce essentially the same pollutants, although the quantity of each substance may vary from source to source.

2. Pollution by motor vehicles: Gaseous and vapour pollution are obtained from motor vehilces.

In many cities around the world motor vehicles are the principal source of NOx emissions. . However, the pollution-control devices perform satisfactorily only when properly maintained. Poor maintenance, tampering, and insufficient monitoring and inspection make the attainment of air quality standards problematic. Another source is rubber.Rubber particles from tires contribute to air pollution and to   pollution as they are washed out with storm water into the watershed.

3. Pollution by incinerators: Another concern is the emission of airborne toxins by municipal and toxic waste incinerators. With the growing shortage of waste disposal sites and the increase in the cost of disposal, municipalities in and around the industrialized world are tending to dispose of municipal waste by incineration and to use the heat produced for energy generation.

Facility Effectiveness _ Although modern incinerators may meet the air quality standards for conventional pollutants, there is a concern for incineration of chlorine-containing compounds, such as bleached paper and poly(vinyl chloride) plastics, produces toxic (and until recently, unregulated) dioxins and furans.

Chemical Waste - Waste incinerators contribute significantly to air pollution by emitting toxic metals such as mercury, lead, zinc, cadmium, tin and antimony. Reports have indicated that people living in close vicinity to toxic waste incinerators had a greater prevalence of coughing, phlegm, wheezing, sore throat, eye irritation, empysema, sinus trouble and neurological diseases than those living some distance from the incinerators.

4. Indoor air pollution: The main source of indoor air pollution in the developing countries is combustion of coal or biomass (wood, dung, agricultural waste, etc.) for heating and cooking in primitive, poorly vented stoves. The pollutants in that case are respirable particles coated with PAHs, nitrogen dioxide, sulfur dioxide, carbon monoxide, and a variety of VOCs.

Most of these pollutants are either irritants of tender tissues, respiratory and cardiovascular toxins, or both. In addition, some PAHs are carcinogens and mutagens mostly affecting the respiratory system. Sometimes, especially in rural houses, the concentration of certain indoor pollutants exceeds the WHO guidelines. Because women in the agricultural communities spend most of their time indoors performing household chores, exposure to fumes of biomass fuels might be the single most important health hazard for women.

UNIT 4 WATER AND LAND POLLUTION

CONTENTS

4.1 Introduction

Water pollution refers to the contamination or pollution of the water bodies or its source, which usually occurs as a result of human activities

Land pollution is the deterioration or degradation of earth's surface or soil. It is the deposition of solid or liquid materials in the land in a way which can contaminate the soil and groundwater and even threaten public health.

In this unit we shall examine water and land pollution; freshwater reserves, urban pollutants and industrial pollutants

4.2 Learning Outcomes

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

- discuss the following in relation to water and land pollution

a) freshwater reserves

b) nitrogen overload

- discuss the ways of pollutants transport into water
- discuss industrial pollutants
- analyse the sources of urban pollutants

- **Preamble**

Water and soil pollutants represent two major categories of environmental pollution. Water and soil- polluting substances are often due to man-made wastes such as household garbage, manufacturing and agricultural wastes, fertilizers used by farmers, oil spills, and radioactive materials.

4.3 Freshwater Reserves

The amount of freshwater is maintained constant by the hydrological cycle. This cycle involves evaporation from oceans and inland waters, transpiration from plants, precipitation, infiltration into the soil, and runoff of surface water into lakes and rivers. The infiltrated water is used for plant growth and recharges groundwater reserves.

Although the global supply of available freshwater is sufficient to maintain life, the worldwide distribution of freshwater is not even. In some areas the supply is limited because of climatic conditions or cannot meet the demands of high population density. In other places, although there is no shortage of freshwater, the water supply is contaminated with industrial chemicals and is thus unfit for human use. Moreover, fish and other aquatic species living in chemically contaminated water become unfit for human consumption. Thus, water pollution deprives us and other species of two essential ingredients for survival: water and food.

In the urban setting, pervious areas are replaced with impervious ones (such as streets, parking lots, and shopping centers). Groundwater replenishment is greatly reduced and runoff is considerably increased by these changes. Thus, urbanization not only contributes to water pollution; it also increases the possibility of floods.

- **Nitrogen Overload**

As humanity became increasingly dependent on fossil fuels and nitrogen containing fertilizers, the production of nitrogen oxides increased substantially. The inorganic nitrogen compounds began to accumulate in the soil as the denitrifying microorganisms are unable to deal with the overload. The nitrates and nitrites deposited on the land percolate through the soil and pollute the groundwater. They are also washed out with agricultural runoff into rivers, lakes and estuaries promoting an excessive growth of algae and other aquatic plants. Growth of microorganisms and bacterial digestion of the decaying plants consume the oxygen dissolved in the water, a process called eutrophication. Because aquatic species require 5–6 ppm of dissolved oxygen, excessive growth causes oxygen depletion and thus kills fish by suffocation.

- **Transport of water pollutants**

The transport of pollutants into water may occur in three ways:

- Via point sources which have a well-defined origin, such as the outlet from a plant or from a municipal sewer line,

- Via nonpoint sources that lack any well-defined point of origin, such as runoff from fields or streets,
- Via air, with wind or air currents.

Although all types of pollution source present a serious problem, point sources can be controlled, at least in principle. Nonpoint sources are difficult to control, whereas transport in the air is impossible to control at all, and can be prevented only by discontinuing the use of harmful substances.

Self-Assessment Exercises 1

1. Analyse the ways pollutants transport into water.
2. How does nitrogen affects water bodies

4.4 Urban Pollutants

The sources of urban pollutants are municipal sewage, runoff from city streets and landfills, and industrial effluents.

- **Municipal Sewage**

Municipal sewage consists mainly of human and animal waste; thus it is rich in nitrogen-containing organic nutrients. In addition, it contains grit, suspended soil, detergents, phosphates, metals, and numerous chemicals. Raw sewage entering streams and lakes stimulates excessive growth of aquatic bacteria, algae, and other plants leading to eutrophication.

- **Metabolizable Organic Matter**

The degree of pollution with metabolizable organic matter can be determined by a test called biological oxygen demand (BOD). This measures the amount of oxygen needed by aquatic microorganisms to decompose organic matter during a 5-day period. Hence, metabolizable organic pollutants are referred to as BOD pollutants.

- **Synthetic Organic Chemicals**

The synthetic chemicals found in municipal wastewater originate from both household use and industry. Ordinary households in an industrialized society use substantial amounts of organic chemicals such as cleaning fluids, pharmaceuticals, cosmetics, and paints. Residual quantities of these substances may end up in the sewage.

Toxic chemicals in sewage create potential hazards to aquatic life and inhibit the biological process of degradation of contaminants. In addition, they potentiate the toxicity of sewage sludge that must be disposed of in landfills.

- **Storm Water Runoff**

Storm water runoff from cities and villages presents another problem. This runoff contains salts from road deicing, street refuse, animal waste, food litter, residue from atmospheric deposition of sulfuric and nitric acid, metals, asbestos from automobile brakes, rubber from tires, hydrocarbons from motor vehicle exhaust condensates, oil and grease, soil and inorganic nutrients from construction sites, and a variety of other chemicals.

After a heavy downpour, the runoff from city streets and construction sites and leachates from landfills may bring a considerable quantity of pollutants into streams and lakes.

- **Lead Pollution**

Although lead pollution is essentially an urban problem, agricultural land, lakes, and rivers are also frequently affected. Lead has many toxic effects, including inhibition of red blood cell formation, kidney damage, and damage to the nervous system.

- **Sources**

The sources of lead pollution are leaded gasoline, lead-based paint, and waste disposal.

- **Toxic Symptoms in Children**

Children are particularly susceptible to low-level lead intoxication, which creates a type of encephalopathy referred to as subclinical toxicity.

- **Soil Erosion**

Soil erosion is a natural phenomenon caused by water and wind. ; it causes silting of lakes and rivers, it causes pollution of surface water with nutrients and pesticides, and it affects the fertility of the land.

- **Binding of Pollutants**

The capability of soil to bind and transport pollutants depends on the nature of the soil as well as on the chemical and physical properties of the pollutant.

Soil organic matter is responsible for binding nonionic and hydrophobic compounds. The inorganic matter interacts with ionic and polar compounds; it also has cation-exchange capacity. The size of soil particles is important. The large surface area associated with very small particles provides a greater number of binding sites than the surface area of large particles. Water solubility of a pollutant is another property that affects its interaction with the soil. Water solubility, in turn, is affected by factors such as salt concentration, pH, the presence of other organic compounds, and temperature.

- **Cropland Fertility**

Soil erosion is an important issue because it contributes to water pollution and affects cropland fertility. Although the predominant effect of erosion is loss of the topsoil, in some extreme cases soil erosion leads to terrain deformation by creation of gullies. Other causes of land degradation are depletion of nutrients, compaction of the soil by cattle or heavy machinery, waterlogging, salinization, and acidification.

- **Salinization**

Excessive salt accumulated in the upper layers or on the surface of the soil inhibits plant growth, and consequently the fertility of the land declines. In extreme cases certain areas may become sterile.

- **Nutrients and Pesticides**

Runoff from farms causes pollution by nutrients such as nitrates and phosphates from fertilizers and by animal waste originating from feedlots. Both nutrients and animal waste contribute to eutrophication of lakes and streams.

- **Nutrients**

Nitrates are of special concern because of their potential toxicity. With their high water solubility, they leach easily from the soil and contaminate surface as well as groundwater. In the soil they may undergo reduction to nitrites. When ingested via drinking water, nitrites may cause methemoglobinemia and hypertension in children.

The chemical reaction between nitrites and some pesticides may lead to formation of nitrosamines, which are known carcinogens and mutagens.

Phosphates move primarily with the eroding soil. Even when applied to the field as a soluble orthophosphate, it soon reverts to an insoluble form that is readily adsorbed to soil particles. As a result, phosphate builds up in the sediment. Manure is a good fertilizer if used in moderate quantities on the fields. Large quantities of manure that accumulate in cattle feedlots produce leachate rich in organic nutrients as well as in phosphates, nitrates, and ammonia, creating a hazard of groundwater and surface water pollution.

The accumulated manure also contributes to air pollution by releasing nitrous oxide, which is formed in the soil from ammonia by oxidizing bacteria. N_2O is converted in the air to nitric acid.

- **Pesticides**

Pesticides (whether insecticides, herbicides, or fungicides) by their very nature and purpose are poisons. Even if their amount is minimal in comparison to that of silt, their impact on the environment may be considerable.

- **Persistence in the Environment**

Concern with pesticides centers on their properties, such as selective toxicity, persistence in the environment, bioaccumulation potential, and mobility. Persistence in the environment is perhaps the most crucial factor in their acceptability. Accordingly, they are divided into three groups:

persistent, which decompose by 75–100% within 2–5 years; moderately persistent, which decompose within 1–18 months; and nonpersistent, which decompose in 1–12 weeks.

The fact that a pesticide ‘‘decomposes’’ (i.e., loses the activity for which it was designed) does not necessarily mean that it becomes a harmless substance.

- **Restriction**

Some of the most persistent pesticides (such as DDT, dieldrin, chlordane, and toxaphene) have been banned from use, and the use of others has been restricted.

Table 1 Main Classes of Pesticides and Their Characteristics

Class	Use	Persistence	Solubility in Water	Transport in Soil
Chlorinated hydrocarbons	Insecticides	High	Extremely poor to insoluble	Soil erosion
Cationic heterocyclics	Herbicides	High	Good	Soil erosion
Triazines	Herbicides	Moderate	pH dependent	Soil erosion
Phenylureas	Herbicides	Moderate	Variable	Leaching (if highly soluble)
Dinitroanilines	Herbicides	Moderate	Poor	Soil erosion
Phenoxyacetic acid derivatives	Herbicides	Short	Good	Soil erosion
Phenylcarbamate derivatives	Herbicides	Short	Good	Soil erosion
Ethylenebis (dithiocarbamate) metal derivatives	Fungicides	Short	Moderate	Unknown
Pyrethroids	Insecticides	Short	Extremely poor	Soil erosion
Organophosphorus	Insecticides	Short	Good	Leaching
Carbamates	Insecticides	Short	Good	Leaching

- **Health and Environmental Effects**

Concern about the health effects of chlorinated hydrocarbon pesticides stems from the observation that many of them, such as DDT, aldrin, and chlordane, were shown to produce liver cancer in rodents. Recently, concern about effects of pesticides on human health and on the ecosystem began to move beyond cancer. It appears that some chlorinated hydrocarbon pesticides exert a multitude of toxic effects. These pesticides are neurotoxic, mutagenic, and teratogenic, they exert toxic effects on the reproductive system, and they suppress the immune system. It has been suggested that these compounds act by mimicking or inhibiting estrogen receptors. Endocrine disrupters, as they are called not only affect women's health, but are also believed to be responsible for a decrease in sperm count and a rise in testicular cancer in humans.

Because of the environmental problems caused by persistent pesticides, there is now a tendency to use, whenever possible, the non-persistent ones that by definition decompose in 1–12 weeks.

- **Alternative Agriculture**

Public concern over the presence of pesticide residues in fruits and vegetables and water pollution problems caused by conventional agricultural practices have led to a new trend in food production, alternative agriculture. The aim of alternative agriculture is to limit dependence on fertilizers and pesticides and to prevent soil erosion. The techniques involve crop rotation, diversification of crops and livestock, use of nitrogen-fixing legumes, use of biological pest control, new tillage procedures, and planting cover crops after the harvest to prevent soil erosion. Although alternative agriculture is at present in an experimental stage, it may eventually offer a means to sustainable and nonpolluting food production.

Self-Assessment Exercises 2

1. Enumerate are the sources of urban pollution
2. What is the impact of soil erosion on crop productivity?

4.5 Industrial Pollutants

Industrial waste consists of a variety of pollutants, including sludges from the steel industry; toxic chemicals from chemical, mining, and paper industries; BOD contaminants from food processing plants; heat from power plants (conventional and nuclear) and from steel mills; and pH changes from the mining industry.

These Pollutants represent a hazard not only to aquatic life, but also to human health, either through direct exposure or indirectly through consumption of contaminated fish or waterfowl. The degree of hazard depends on the pollutants' toxicity, rate of discharge, persistence and distribution in the aquatic system, and bioaccumulation potential. Persistence is a function of the toxins' biodegradability in water and of their vapor pressure. Some highly volatile compounds, when discharged into water, evaporate and become air pollutants.

- **Heat Pollution**

Power plants, conventional as well as nuclear, and the steel industry use large amounts of water for cooling purposes. The released water carries heat from the plants into rivers or lakes, and this heat increases the ambient water temperature in the vicinity of the release point.

The elevated temperature stimulates the metabolism of aquatic organisms, which in turn increases the demand for oxygen. At the same time, the amount of dissolved oxygen decreases with increasing temperature. Thus, the effect of heat pollution is similar to that of BOD contaminants or nutrients.

Some aquatic species have difficulty adapting to the warmer environment. Other species adapt to the warmer water and congregate around discharge points in winter. If the plants are shut down temporarily, massive fish kills from temperature shock result.

- **Pollution of Groundwater**

Although there are numerous sources of contaminants, they are all related to three potential roots:

1. water-soluble products that are stored or spread on the land surface
2. substances that are deposited or stored in the ground above the water table
3. material that is stored, disposed of, or extracted from below the water table

Agricultural pollutants and waste disposed on land belong to the first category; waste disposed in landfills, leaking septic tanks, and leaking underground storage tanks, to the second one; and waste disposed in deep wells and waste originating from mining activities to the third.

Essentially, all chemicals that contact the ground, such as fertilizers and pesticides spread on the fields, especially if they are water soluble, present a potential hazard of groundwater contamination.

Self-Assessment Exercises 3

1. Discuss industrial pollutants.
2. Discuss heat pollution.
3. Discuss pollution of groundwater

4.6 Summary

Pollution is making the environment unsafe and unsuitable. It is the addition of any substances or any form of energy to the environment at a rate faster than it can be dispersed, diluted, decomposed, recycled, or stored in some harmless form. The two major pollutions discussed in this unit, are water and land pollutions.

In this unit we examined water and land pollution; freshwater reserves, urban pollutants and industrial pollutants

4.7 References/Further Reading

Environmental Toxicology, Third Edition, Sigmund F. Zakrzewski ,Oxford University Press retrieved from http://pustaka.unp.ac.id/file/abstrak_kki/EBOOKS/Environmental%20Toxicology%203rd%20edition.pdf

4.8 Possible Answers to Self-Assessment Exercises

Self-Assessment Exercises 1

1. Analysis of the ways pollutants transport into water: The transport of pollutants into water may occur in three ways: Via point sources, which have a well-defined origin, such as the outlet from a plant or from a municipal sewer line; via nonpoint sources that lack any well-defined point of origin, such as runoff from fields or streets and via air, with wind or air currents. Although all types of pollution sources present a serious problem,

point sources can be controlled, at least in principle. Nonpoint sources are difficult to control, whereas transport in the air is impossible to control at all, and can be prevented only by discontinuing the use of harmful substances.

2. Excess nitrogen can cause overstimulation of growth of algae and other aquatic plants. Growth of microorganisms and bacterial digestion of the decaying plants consume the oxygen dissolved in the water, a process called eutrophication. Because aquatic species require 5–6 ppm of dissolved oxygen, excessive growth causes oxygen depletion and thus kills fish by suffocation.

Self-Assessment Exercises 2

1. The sources of urban pollutants are municipal sewage, runoff from city streets and landfills, and industrial effluents.
2. Soil erosion induced reduction in crop yield is attributed to loss of rooting depth, gegradation of soil structure, decrease in plant-available water reserves, reduction in organic matter, and nutrient imbalance.

Self-Assessment Exercises 3

1. Industrial pollutants: Industrial waste consists of a variety of pollutants, including sludges from the steel industry; toxic chemicals from chemical, mining, and paper industries; BOD contaminants from food processing plants; heat from power plants (conventional and nuclear) and from steel mills; and pH changes from the mining industry.

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Some aquatic species have difficulty adapting to the warmer environment. Other species adapt to the warmer water and congregate around discharge points in winter. If the plants are shut down temporarily, massive fish kills from temperature shock result.

3. Pollution of groundwater: Although there are numerous sources of contaminants, they are all related to three potential roots: water-soluble products that are stored or spread on the land surface, substances that are deposited or stored in the ground above the water table and material that is stored, disposed of, or extracted from below the water table

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Essentially, all chemicals that contact the ground, such as fertilizers and pesticides spread on the fields, especially if they are water soluble, present a potential hazard of groundwater contamination.

UNIT 5 ENVIRONMENTAL POLICIES AND FUTURE OF FOOD ADDITIVES

CONTENTS

5.1 Introduction

Environmental policy is the commitment of an organization or government to the laws, regulations, and other policy mechanisms concerning environmental issues. These issues generally include air and water pollution, waste management, ecosystem management, maintenance of biodiversity, the management of natural resources, wildlife and endangered species. Policies concerning energy or regulation of toxic substances including pesticides and many types of industrial waste are part of the topic of environmental policy. This policy can be deliberately taken to influence human activities and thereby prevent undesirable effects on the biophysical environment and natural resources, as well as to make sure that changes in the environment do not have unacceptable effects on humans.

In this unit we shall examine environmental policies and future of food additives; history of environmental policy making, environmental policy instruments, global policy agreements and future of food additives.

5.2 Learning Outcomes

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

- discuss environmental policy
- discuss the history of environmental policy making
- discuss the characteristics of regulations
- analyse the instruments used by decision makers for environmental monitoring.
- evaluate the factors to consider in the future of food additives

5.3 Environmental Policy

Environmental policy refers to any measure by a government or corporation or other public or private organization regarding the effects of human activities on the environment, particularly those measures that are designed to prevent or reduce harmful effects of human activities on ecosystems.

Environmental policies are needed because environmental values are usually not considered in organizational decision making. There are two main reasons for that omission. First, environmental effects are economic externalities. Polluters do not usually bear the consequences of their actions; the negative effects most often occur elsewhere or in the future. Second, natural resources are almost always under-priced because they are often assumed to have infinite availability. Together, those factors result in what American ecologist Garrett Hardin in 1968 called “the tragedy of the commons.” The pool of natural resources can be considered as a commons that everyone can use to their own benefit. For an individual, it is rational to use a common resource without considering its limitations, but that self-interested behaviour will lead to the depletion of the shared limited resource—and that is not in anyone’s interest. Individuals do so nevertheless because they reap the benefits in the short term, but the community pays the costs of depletion in the long term. Since incentives for individuals to use the commons sustainably are weak, government has a role in the protection of the commons.

5.3.1 History of environmental policy making

Public policies aimed at environmental protection date back to ancient times. The earliest sewers were constructed in Mohenjo-daro (Indus, or Harappan, civilization) and in Rome (ancient Roman civilization), which date back some 4,500 years and 2,700 years ago, respectively. Other civilizations implemented environmental laws. The city-states of ancient Greece created laws that governed forest harvesting some 2,300 years ago, and feudal European societies established hunting preserves, which limited game and timber harvesting to royalty, effectively preventing overexploitation, by 1000 CE. The city of Paris developed Europe’s first large-scale sewer system during the 17th century. When the effects of industrialization and urbanization increased during the late 19th and early 20th centuries and threatened human health, governments developed additional rules and regulations for urban hygiene, sewage, sanitation, and housing, as well as the first laws devoted to protecting natural landscapes and wildlife.

People became aware of the harmful effects of emissions and use of chemicals in industry and pesticides in agriculture during the 1950s and ’60s. The emergence of Minamata disease in 1956 in Japan, which resulted from mercury discharges from nearby chemical companies, and the publication of *Silent Spring* (1962) by American biologist Rachel Carson, which highlighted the dangers of pollution, led to a greater public awareness of environmental issues and to detailed systems of regulations in many industrialized countries.

In those regulations, governments forbade the use of hazardous substances or prescribed maximum emission levels of specific substances to ensure a minimum environmental quality. Such regulative systems, succeeded in effectively addressing point sources (i.e., any discernable discrete location or piece of equipment that discharges pollution), such as industrial plants and utilities, where the cause-and-effect relationship between the actors causing the negative environmental effect could be clearly established.

Nevertheless, some environmental problems persisted, often because of the many nonpoint (diffuse) sources, such as exhaust from private automobiles and pesticide and fertilizer runoff from small farms, that contributed to air and water pollution. Individually, those small sources may not be harmful, but the accumulation of their pollution can exceed the regulative minimum norms for environmental quality. Also, the increasing complexity of chains of cause and effect has contributed to persistent problems. In the 1980s the effects of acid rain showed that the causes of environmental pollution could be separated geographically from its effects. Pollution problems of all types underscored the message that Earth's natural resources were being depleted and degraded.

From the late 1980s, sustainable development—(i.e., the fostering of economic growth while preserving the quality of the environment for future generations—became a leading concept in environmental policy making. With nature and natural resources considered as economic drivers, environmental policy making was no longer the exclusive domain of government. Instead, private industry and nongovernmental organizations assumed greater responsibility for the environment. Also, the concept emphasized that individual people and their communities play a key role in the effective implementation of policies.

Self-Assessment Exercises 1

1. What is environmental policy?
2. Why are environmental policies needed?

5.4 Environmental Policy Instruments

Numerous instruments have been developed to influence the behaviour of actors who contribute to environmental problems. Traditionally, public policy theories have focused on regulation, financial incentives, and information as the tools of government. However, new policy instruments such as performance requirements and tradable permits have been used.

5.4.1 Regulation

Regulation is used to impose minimum requirements for environmental quality. Such interventions aim to encourage or discourage specific activities and their effects, involving particular emissions, particular inputs into the environment (such as specific hazardous substances), ambient concentrations of chemicals, risks and damages, and exposure.

- **Characteristics of Regulation**

1) Permit - Often, permits have to be acquired for those activities, and the permits have to be renewed periodically. In many cases, local and regional governments are the issuing and controlling authorities. However, more-specialized or potentially hazardous activities, such as industrial plants treating dangerous chemical substances or nuclear power stations using radioactive fuel rods, are more likely to be controlled by a federal or national authority.
2) Strength - The strengths of regulation are that it is generally binding—it includes all actors who want to undertake an activity described in the regulation—and it treats them in the same framework.
3) Rigidity - Regulations are also rigid: they are difficult to change. That can be considered as a strength, since rigidity ensures that regulations will not change too suddenly. However, rigidity can also be considered a weakness, because it slows down innovation, as actors seek to stay within the letter of the law rather than creating new technologies.
4) Standards - When regulations demand standards that are difficult or impossible to meet—because of a lack of knowledge, skills, or finances on the part of the actors or mismanagement by policymakers—regulations will not be effective.

5) Performance Requirement - One common improvement in environmental regulation made since the 1970s has been the development of performance requirements, which allow actors to determine their own course of action to meet the standard. For example, they are not required to purchase a particular piece of equipment to meet an emissions standard. They can do it another way, such as developing a technology or process that reduces emissions. The advantage of performance requirements is that actors addressed by the regulation are encouraged to innovate in order to meet the requirements. Despite that advantage, performance requirements cannot keep actors who lack incentives from achieving more than the minimum requirements.

5.4.2 Financial Incentives

Governments can decide to stimulate behavioural change by giving positive or negative financial incentives—for example, through subsidies, tax discounts, or fines and levies. Such incentives can play an important role in boosting innovation and in the diffusion and adoption of innovations. Financial incentives or disincentives can also stimulate professional actors to change. A potential drawback of financial incentives is that they distort the market. When not used for a limited period, they can make receivers dependent upon the subsidy. A final drawback is that subsidies are expensive instruments, especially when they are open-ended.

5.4.3 Environmental Reporting and Ecolabeling

There are several instruments that aim to inform decision makers about the environmental effects of their actions.

1) The Environmental Impact Assessment

The environmental impact assessment (EIA) is an instrument that helps public decision makers to decide on initiatives with a certain environmental impact, such as the construction of roads and industrial plants. The EIA, which has become a legal requirement in many countries, requires that the environmental effects of a project, such as the building of a dam or shopping mall, be studied and that the actors be informed of how to mitigate environmental damage and what compensation they could receive for doing so. EIAs allow decision makers to include environmental information in a cost-benefit analysis. Although all EIAs cannot stop initiatives from taking place, they can reduce the negative environmental impacts.

2) Environmental Management Systems

Environmental management systems are comprehensive approaches that help organizations reduce their use of natural resources while reducing costs and—when certified—contributing to a positive image. The most commonly known standard for such systems is the ISO 14000 standards, first issued by the International Organization for Standardization (ISO) in 1996. Such standards help an organization control its environmental impact, formulate and monitor environmental objectives, and demonstrate that they have been achieved.

3) Ecolabels

Ecolabels and certificates applied to specific products and services inform consumers about their environmental performance. Sometimes governments require such labels and certificates, which certifies that a product has met minimum requirements for consumer safety, health, and environmental friendliness. To push organizations to develop products and services that perform beyond those minimum requirements, there are labels that specifically express the environmental friendliness of the product or service.

Ecolabels are often applied in the food industry (such as for certified organic or fair-trade certified products) and for energy performance in LEED standards the underlying assumption of ecolabeling is that informed consumers buying environmentally responsible products will stimulate industry to innovate and produce cleaner products.

Self-Assessment Exercises 2

1. Discuss the characteristics of regulations.
2. Analyse the instruments used by decision makers for environmental

5.5 Global Policy Agreements

From the early 1970s, the United Nations (UN) has provided the main forum for international negotiations and agreements on environmental policies and objectives. The 1972 Stockholm conference was the first international conference on environmental issues and was followed by the United Nations Conference on Environment and Development (UNCED) summits in Rio de Janeiro in 1992 and in Johannesburg in 2002. The UN also hosted special conferences on climate change, such as those of 1996 in Kyoto and 2009 in Copenhagen.

Those conferences and summits responded to the global character of some of the most-challenging environmental problems, which would require international cooperation to solve.

5.5.1 Future of Food Additives

1. Market Overview

Food additives are substances added to foods that help improve the texture, color, taste, or chemical preservatives, appearance, or function of processors. These food additives are often added in minimal amounts to enhance the visual appearance, flavor, texture, and other storage properties. Food additives offer several advantages, such as preventing spoilage of food during storage, transport, distribution or processing, more than 3,000 different compounds are used as food additives. A wide range of food additives such as preservatives, antioxidants, flavour enhancers, colorants, and sweeteners are used in the manufacture or preservation of a variety of foods, packaged foods, functional drinks, bakery products, dairy products, meat, and seafood.

In addition to the list of food additives mentioned above, enzymes, emulsifiers, acidulants, shelf life stabilizers and fat substitutes are in high demand in the global food additives market. Food additives are in high demand due to general requirements from the food industry, end consumers, and regulators around the world. Food additives are used in various applications such as bakery and confectionery, dairy and frozen desserts, beverages, meat and poultry products, and other products including sauces, soups, and baby food to improve the sweetness and enhance or add color and avoid spoilage of food.

2. Drivers

A consumption of high-nutrient foods are beverages with improved visual appeal increases, market demand is assumed to increase during the forecast period. The global food additive industry is expected to witness growth due to changes in consumer taste and interest in product quality and nutritional value. Increased consumer awareness of different types of flavours is also likely to play an essential role in driving growth. To enhance protection against harmful bacteria and other types of microorganisms to extend shelf life, additives are included in the finished product. It also imparts properties such as the taste, colour, and taste of foods, as well as increases nutritional content. Food additives are elements added to foods to improve specific features, such as taste, consistency, flavour, light-protection surface, and shelf life. There are two essential food additives on the market: instant food packaging and indirect food additives. Since there is no real option for food additives, the development of the food and beverage industry may influence decisions in the global market.

The global market for food additives is anticipated to withstand fragmented properties as there are many organizations and a variety of affordable items that add to the food business. For example, the problem of well-being will help obesity among young people and adults to demand useful food additives in the market. Interest in natural food additives is assumed to increase markedly as shoppers become more wellness conscious and perceive the detrimental effects of manufactured food tones. As the demand to packaged products, including ready-to-eat foods, snacks, and frozen meals increases, manufacturers are expected to increase production capacity and increase demand.

The growing consumer demand for exotic flavors and high-value nutritional products is driving manufacturers to develop ingredients that enhance the consumer experience. Population growth, coupled with rising food demand, is expected to be a significant driver of the global market for food additives. In addition, consumer demand for quality food is foreseen to drive the growth of the food additive business in the coming years. Emerging markets around the world are expected to offer opportunities for the food additive market in the near future.

3. Restraints

In particular, the increased demand for premium foods in developed countries is estimated to play an essential role in the growth of the food additive market. However, the strict regulations established by regulatory agencies such as the European Food Safety Authority, the Food and Drug Administration and the European Union Law on the Safety of Food Additives can serve as a deterrent to the global market for food additives. Furthermore, the limited solubility and high cost of natural food additives are expected to serve as inhibitors for the food additive market. The market has been limited due to increased consumer demand for synthetic additives, increased consumer demand for "additive-free" foods or products containing natural additives, limited availability and high cost of natural food additives, and increased consumer conversion to organic food growth in recent years.

Self-Assessment Exercises 3

1. What does the international environmental policies cover?
2. Discuss the effect of the restraints on the future of food additives

5.6 Summary

Environmental policy is primarily concerned with how to govern the relationship between humans and the natural environment in a mutually beneficial manner. Traditionally, it has been defined in terms of the problems it addressed, such as controlling pollution and waste flows and limiting habitat loss. However, policy makers have begun to appreciate that environmental policy will only be genuinely successful when it is sensitively integrated with other sectors and policy areas.

The use of technological food additives is currently the subject of a controversy related to the potential impacts these can have on human health. Perhaps the most significant trend driving growth in additives is a general increase in processed foods consumption across the world.

In this unit we examine environmental policies and future of food additives; history of environmental policy making, environmental policy instruments, global policy agreements and future of food additives.

5.7 Glossary

Additive: A substance added to something in small quantities to improve or preserve it

Contaminants: A substance that pollutes, spoils, or poisons something

Copolymer: Is a polymer consisting of two or more different monomers.

Environmental: Of or relating to the external conditions or surroundings; concerned with the ecological effects of altering the environment.

Food additives: Any substance that is added to food with the intention of improving its flavour or appearance or shelf-life or nourishment.

Incentive: It is a positive motivational influence

Incinerator: It is a furnace for burning substances to ashes (especially to dispose of refuse and wastes).

Industrial: Of or relating to or resulting from industries.

Lubricant: A substance capable of reducing friction by making surfaces smooth or slippery.

Monitoring: It is an act of observing a thing or process (and sometimes keeping a record of it).

Monomers: They are simple compounds whose molecules can link with one another to form polymers.

Motor (or automotive) vehicle: It is self-propelled wheeled vehicle that runs on roads rather than on rails.

Noise: It is an unintelligible or dissonant sound of any kind.

Nutrient: It is any substance that can be metabolized by an organism to give energy and build tissues; of or providing nourishment.

Nylon: It is a thermoplastic polyamide; a family of strong resilient synthetic fibers.

Oligomer: It is a compound whose molecules are composed of three or four monomers.

Packaging: It is a business of packing things; a material used by producers or middle men to pack goods for consumers.

Pesticide: It is a chemical that is used to kill pests such as rodents and insects.

Plasticizer: A substance that is added to plastics or other matherials to make them more pliable.

Policy: It is a plan of action adopted by an individual or a social group.

Pollutant: It is waste matter that contaminates the air or water or soil.

Polyethylene: it is (also called polythene) is a lightweight thermoplastic used especially in packaging and insulating).

Polymer: It is a natural or synthetic compound consisting of giant molecules that are made up of a linked series of repeated monomers.

Resin: Any of a class of solid or semisolid viscous substances obtained either as exudants from certain plants or prepared by polymerization of simple molecules.

Salinization: It is an act or process of increasing the concentration of salt to a thing or an environment.

Sewage: It is waste matter that is carried away in sewers or drains.

Thermoplastic: It is a material that softens when heated and hardens, and becomes rigid, again when cooled.

Thermoset: It is the property of becoming permanently hard and rigid when heated or cured.

Toxicity: It is the degree to which a chemical substance or a particular mixture of substances can damage an organism

Waste: It is any material that is unused and rejected as worthless or unwanted.

Waterwaste: It is unwanted domestic or industrial water runoff from the site into the environment.

5.8 References/Further Reading

Bueren, Ellen van. "environmental policy". Encyclopedia Britannica, 11 Feb. 2019, https://www.britannica.com/topic/environmental-policy. Accessed 6 June 2022.

https://www.marketdataforecast.com/market-reports/global-food-additives-market

5.9 Possible Answers to Self-Assessment Exercises

Self-assessment Exercises 1

1. Environmental policy refers to any measure by a government or corporation or other public or private organization regarding the effects of human activities on the environment, particularly those measures that are designed to prevent or reduce harmful effects of human activities on ecosystems.
2. Environmental policies are needed because environmental values are usually not considered in organizational decision making. There are two main reasons for that

omission. First, environmental effects are economic externalities. Polluters do not usually bear the consequences of their actions; the negative effects most often occur elsewhere or in the future. Second, natural resources are almost always under-priced because they are often assumed to have infinite availability. Together, those factors result in what American ecologist Garrett Hardin in 1968 called “the tragedy of the commons.” The pool of natural resources can be considered as a commons that everyone can use to their own benefit. For an individual, it is rational to use a common resource without considering its limitations, but that self-interested behaviour will lead to the depletion of the shared limited resource—and that is not in anyone’s interest. Individuals do so nevertheless because they reap the benefits in the short term, but the community pays the costs of depletion in the long term. Since incentives for individuals to use the commons sustainably are weak, government has a role in the protection of the commons.

Self-assessment Exercises 2

1. Characteristics of regulations:

- Permit - Often, permits have to be acquired for those activities, and the permits have to be renewed periodically. In many cases, local and regional governments are the issuing and controlling authorities. However, more-specialized or potentially hazardous activities, such as industrial plants treating dangerous chemical substances or nuclear power stations using radioactive fuel rods, are more likely to be controlled by a federal or national authority.
- Strength - The strengths of regulation are that it is generally binding—it includes all actors who want to undertake an activity described in the regulation—and it treats them in the same framework.

- Rigidity - Regulations are also rigid: they are difficult to change. That can be considered as a strength, since rigidity ensures that regulations will not change too suddenly. However, rigidity can also be considered a weakness, because it slows down innovation, as actors seek to stay within the letter of the law rather than creating new technologies.
- Standards - When regulations demand standards that are difficult or impossible to meet—because of a lack of knowledge, skills, or finances on the part of the actors or mismanagement by policymakers—regulations will not be effective.
- Performance Requirement - One common improvement in environmental regulation made since the 1970s has been the development of performance requirements, which allow actors to determine their own course of action to meet the standard. For example, they are not required to purchase a particular piece of equipment to meet an emissions standard. They can do it another way, such as developing a technology or process that reduces emissions. The advantage of performance requirements is that actors addressed by the regulation are encouraged to innovate in order to meet the requirements. Despite that advantage, performance requirements cannot keep actors who lack incentives from achieving more than the minimum requirements.

2. Analysis of the instruments used by decision makers for environmental monitoring:

There are several instruments that aim to inform decision makers about the environmental effects of their actions.

a) The Environmental Impact Assessment: The environmental impact assessment (EIA) is an instrument that helps public decision makers to decide on initiatives with a certain environmental impact, such as the construction of roads and industrial plants. The EIA, which has become a legal requirement in many countries, requires that the environmental effects of a project, such as the building of a dam or shopping mall, be studied and that the actors be informed of how to mitigate environmental damage and what compensation they could receive for doing so. EIAs allow decision makers to include environmental information in a cost-benefit analysis. Although all EIAs cannot stop initiatives from taking place, they can reduce the negative environmental impacts.

b) Environmental Management Systems: Environmental management systems are comprehensive approaches that help organizations reduce their use of natural resources while reducing costs and—when certified—contributing to a positive image. The most commonly known standard for such systems is the ISO 14000 standards, first issued by the International Organization for Standardization (ISO) in 1996. Such standards help an organization control its environmental impact, formulate and monitor environmental objectives, and demonstrate that they have been achieved.

c) Ecolabels: Ecolabels and certificates applied to specific products and services inform consumers about their environmental performance. Sometimes governments require such labels and certificates, which certifies that a product has met minimum requirements for consumer safety, health, and environmental friendliness. To push organizations to develop products and services that perform beyond those minimum requirements, there are labels that specifically express the environmental friendliness of the product or service. Ecolabels are often applied in the food industry (such as for certified organic or fair-trade certified products) and for energy performance in LEED standards. The underlying assumption of ecolabeling is that informed consumers buying environmentally responsible products will stimulate industry to innovate and produce cleaner products.

Self-assessment Exercises 3

1. International environmental policy covers a number of issues: climate protection, sustainable energy policy, preservation of biological diversity and the conservation of forests, seas and soils. Further related topics are desertification, sustainable waste management and protection against hazardous substances.
2. In particular, the increased demand for premium foods in developed countries is estimated to play an essential role in the growth of the food additive market. However, the strict regulations established by regulatory agencies such as the European Food Safety Authority, the Food and Drug Administration and the European Union Law on the Safety of Food Additives can serve as a deterrent to the global market for food additives. Furthermore, the limited solubility and high cost of natural food additives are expected to serve as inhibitors for the food additive market. The market has been limited due to increased consumer demand for synthetic additives, increased consumer demand for "additive-free" foods or products containing natural additives, limited availability and high cost of natural food additives, and increased consumer conversion to organic food growth in recent years.