UNIT 1 AN OVERVIEW OF FOOD CHEMISTRY

Structure

1.0 OBJECTIVES

After reading this unit, you should be able to:

- explain what is food chemistry;
- state the historical developments in food chemistry; and
- discuss the different roles played by food chemistry.

1.1 INTRODUCTION

All of us need food for our survival and well being. We derive our food from the plant kingdom (like cereals, pulses, oilseeds, fruits, vegetables, root crops, etc.) and animal kingdom (like meat, fish, poultry, cow and buffalo, etc.). Do we know what are the constituents (nutrients) of the foods we eat? Do all foods contain the same constituents and in the same proportions or do they differ? Food chemistry has answers for all these. Today we have a fairly good knowledge of nutrient composition of all the common food materials and products so that we are able to plan a nutritionally balanced diet.

You have learnt the importance and methods of food preservation. Though we eat some foods in the raw form like fruits and vegetables, many others are stored for various length of time and consumed after cooking or converting them to some other forms as processed products like different types of wheat breads; various rice preparations, milk and meat products like cheese, yoghurt, sausages; fruit products like juices, jams, preserves; or dried and dehydrated products like mushroom powder. What changes take place in them after the food raw materials are harvested, processed and stored? Food chemistry deals with these.

Now we see numerous new ready to eat products on the grocer's shelf. They were not there 20 years ago. Steadily the numbers are increasing. How nutritious are these foods? We have become very familiar with the term 'food

adulteration' but how to know whether a particular food is adulterated and if so with what it is adulterated? Yes, a food analyst can find it out.

A general overview of these aspects is given in this unit. You will be learning more details of them in the subsequent units.

1.2 WHAT IS FOOD CHEMISTRY?

Food Science deals with the physical, chemical and biological properties of foods as they relate to stability, quality, processing, safety, nutritive value, wholesomeness, convenience and cost. Food Science is an inter-disciplinary subject involving primarily bacteriology, chemistry, biology and engineering. Food chemistry, a major aspect of food science deals with the composition and properties of food and chemical changes it undergoes during handling, processing and storage. Food Chemistry is intimately related to chemistry and biological sciences like biochemistry, botany, zoology and molecular biology. The primary interests of biological scientists include reproduction, growth and physiological and biochemical (morphological) changes that biological substances undergo under environmental conditions that are compatible with life. On the contrary, food chemists are concerned primarily with biological substances that are dead or dying (post harvest physiology of plants and post-mortem physiology of muscle) and changes they undergo when exposed to very wide range of environmental conditions. That is why a food chemist is concerned with conditions suitable for sustaining the residual life processes (post harvest physiology) for example fresh fruits and vegetables during their marketing.

Both in home scale food preparation and commercial food processing, food raw material are converted into convenient forms by pounding or milling of food grains, pulses, etc., oil extraction, extraction of fruit juices, etc. Food chemists are concerned with the chemical properties of these disrupted food tissues. In other words, food chemists have much in common with biological scientists, yet they also have interests that are distinctly different and are of utmost importance to human kinds.

1.3 HISTORY OF FOOD CHEMISTRY

The origin of food chemistry is as old as human civilization and shrouded in obscurity. Until the 20^{th} Century food chemistry did not have a clear identity and its early developments were associated with agricultural chemistry. During the period 1780-1850 many famous scientists made important discoveries, which laid the foundation of food chemistry.

Carl Wilhelm Scheele (1742-1786) is considered as one of the greatest chemist of all time who has done pioneering work in food chemistry. He isolated and studied the properties of lactose from milk, malic acid from apples and citric acid from lemon juice. He also tested a number of fruits for the presence of citric, malic and tartaric acids as well as various new chemical compounds. Antoine Laurent Lavoisier (1743-1794) also investigated the organic acid content a large number of fruits. He was perhaps the first to show that the process of fermentation could be expressed as a balanced equation. Theodore de Saussure (1767-1845) studied the CO_2 and O_2 exchange during plant

respiration and determined the mineral contents of plants by ashing. Joseph Louis Gay-Lussac (1778-1850) and Louis-Jacques Thenard (1777-1857) devised the first method to determine the percentages of carbon, hydrogen and nitrogen in vegetables. Sir Humphrey Davy (1778-1829) who isolated the elements K, Na, Ba, Sr, Ca and Mg wrote books on agricultural chemistry. In his book elements of Agriculture Chemistry (1813) he stated "the most essential vegetable substances consist of hydrogen, carbon and oxygen in different proportion, generally alone, but in some few cases combined with azote (nitrogen).

Jons Jacob Berzelius (1779-1848) determined the elemental composition of about 2000 compounds there by verifying the law of definite proportions.Justus von Liebig (1803-1873) classified foods as either nitrogenous (vegetable fibrin, albumin, casein, and animal flesh and blood) or nonnitrogenous (fats, carbohydrates, and alcoholic beverages). He is also credited for perfecting methods for the quantitative analysis of organic substances by combustion. His book "Researches on the Chemistry of Food" is considered by many as the first book on food chemistry.

By the first half of the twentieth century, most of the essential dietary substances, namely carbohydrates, proteins, lipids, vitamins, minerals etc. were discovered and characterised.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is food chemistry?

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2. Name three scientists who have done pioneering work in the development of food chemistry.

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1.4 FUNCTIONS OF FOOD CHEMISTRY

Food chemistry, along with the other discipline of food science and nutrition play a vital role in ensuring nutritious and safe food to the human being. It is needless to state that to accomplish these roles, a thorough knowledge of the detailed chemical (nutritional) composition of foods is of prime importance.

1.4.1 Chemical Composition of Foods

As already mentioned, food chemistry has enabled us to know the nutrient composition of most of the common foods. This knowledge on their nutritional role and importance also accumulated. Nutrition studies showed that the human system require certain nutrients like carbohydrates, proteins and fats in large quantities and some others like vitamins and minerals in much smaller quantities. Therefore, the former group of nutrients were termed "major nutrients" and the latter 'minor nutrients'. Depending on the composition of foods, they were classified as 'carbohydrate rich (starchy) foods (e.g. Cereals, root crops), protein rich foods (e.g. meat, poultry and marine foods, legumes), fatty foods (oil seeds, fatty meat and fish) etc, Fruits and vegetables, in general are good sources of the minor nutrients viz. vitamins and minerals which have protective roles against certain deficiency diseases. Therefore, fruits and vegetables were classified as protective foods.

Knowledge on food composition and nutrition has also enabled planning and designing balanced foods suitable for different age groups, sex, convalescing, etc. Balanced food is a food formulation, which will provide all the nutrients in required quantities. Wherever, a food formulation is still deficient in certain nutrients, this knowledge enabled fortification to supplement them.

Today's nutrition literate consumers are demanding information on the nutrient content of the foods they consume. This has resulted in nutrition labelling of food products, which has become mandatory in some countries. Nutrition label provides information on the nutrient content of a particular food product and also what percentage of the Recommended Dietary Allowance of the nutrient is present in one normal serving of the product. The serving size is expressed in millilitres or grams. It is needless to state that nutrition labelling requires precise chemical analysis of the products.

In addition to the major and minor nutrients mentioned already, a number of bioactive compounds have been isolated from foods especially from fruits, vegetables and herbs. They are collectively termed 'Nutraceuticals' or 'Phytonutrients'. Some of them include: carotenoids, flavonoids, sulphides and thiols and phenolic cyclic compounds. Several of them have been shown to have antioxidative protection of the human body, suppression of cancer growth, improvement of vascular health, retardation of osteoporosis and control of cataracts. These developments have revived the old concept of 'Food as Medicine'.

The knowledge of the chemistry of food constituents has also enabled in modification of foods and food constituents. Production of fermented foods is an example of food modification. A large number of traditional fermented foods have been produced in different countries. Improvements in their processing steps and ensuring consistent quality have been possible due to the

knowledge in the chemical (biochemical) reactions. You will be learning more on this in subsequent units. Production of glucose syrup and high fructose syrup from starch, protein hydrolysates from proteins are examples of modification of food constituents.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Explain how the knowledge of food composition helps in formulating a balanced food.

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2. What is a balanced diet?

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3. Explain nutrition labelling.

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4. What is meant by nutraceuticals?

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1.4.2 Quality Changes in Foods

Quality of a food is a complex combination of several sensory and hidden (intrinsic) attributes. You are familiar with some of the sensory qualities like colour and appearance, firmness, mouth feel, flavour, taste etc. Alterations in these qualities of a food material, like for example, fruits results in value reduction and even rejection by the buyer. All these sensory quality changes are caused by chemical (or biochemical) reactions. For example, loss of the green colour of spinach on storage or cooking is due to degradation of chlorophyll. Similarly, browning of cut apples is initiated due to enzymatic oxidation of phenolic substances. Softening of fruits for example is due to the breakdown of pectins or toughening of meat is due to post mortem chemical changes resulting in pH reduction and tissue hardening. Flavour changes are also due to chemical reactions. For example, flavour change in fatty foods called rancidity is due to oxidation of unsaturated fatty acids. You will be learning more on these in subsequent units. The important point to be understood is that once you know the chemical cause of quality deterioration, it is possible to devise methods to control it.

The hidden quality factors of food are the nutrients content, and absence of adulterants and toxicants. Hidden quality cannot be perceived by sensory means. They have to be assessed by chemical means only. Among the hidden quality characteristics, nutritional quality changes are more important in storage and processing of foods. Among the nutrients, some of the vitamins are sensitive to processing conditions. For example, vitamin C (ascorbic acid) is very heat labile. Knowledge on the chemical kinetics of the reactions has enabled development of High Temperature Short Time processing technique and also non-thermal methods of processing. Breakdown of thiamine (vitamin B1) is well known. Therefore, sulphites are avoided for preservation of foods rich in thiamine. Nutritional evaluation of processed foods has been the subject of intense studies in recent times.

The quality changes in foods during processing and storage are due to two major factors namely product factors and environmental factors. Product factors include the chemical composition of a particular food, its pH, and available water content. Environmental factors of importance are temperature and time, light, access to microbial and insect attack and gas composition of the storage atmosphere. Altering the composition of food products to control quality changes is not easily possible except removal of water (drying) even though in a few cases it has been done. For example, to prevent browning of egg powder, glucose is removed from egg by enzymatically oxidising it.

Temperature effect on quality is to a great extent controlled by storage at low temperatures. One of the major functions of packaging is to prevent or reduce the effect of light on food quality. The effect of gas atmosphere on quality is equally important. When a food product is exposed to the atmosphere (containing about 79% N2 and 21% O2) several oxidative reactions take place. Examples are oxidation of fatty acids, oxidation of ascorbic acid, oxidative changes in flavour and browning reactions. In order to prevent the effect of oxygen in canned foods, the cans are exhausted (steam heating of cans filled with the product before sealing) to expel air, fruit juices are deaerated, antoxidants are added to fatty foods etc. You will be learning these techniques in other units. Another method is to alter the gas atmosphere, especially to

eliminate or reduce oxygen content in the gas atmosphere inside a package. You must have seen pillow packs (bloating pouches) of potato chips. They are filled with nitrogen to prevent browning and also to avoid physical damage to the chips. In the case of fresh fruits and vegetables, complete exclusion of oxygen is harmful. Knowledge of the biochemistry of plant respiration shows that reducing the oxygen concentration and increasing the carbon dioxide concentration can extend the storage life of these commodities. This has led to the development of Modified Atmosphere Packaging (MAP) and Controlled Atmosphere (CA) Storage of fresh fruits and vegetables. In MAP, mostly the gas composition is modified by the respiring commodities while in CA storage, the gas composition is modified physically by introducing or removing the respective gases.

Food adulterants and toxicants in foods have to be monitored to ensure food safety. This is a growing challenge to the food chemist.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Explain the chemical basis of two sensory quality changes.

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2. List the factors responsible for food quality changes.

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3. Explain how the effect of oxygen on quality change can be overcome.

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1.4.3 Safety Evaluation of Foods

Most scientific developments have both benefits and harmful effects. Food chemistry is no exception. The new knowledge gave ample opportunity to unscrupulous purveyors for food adulteration. Practically all foods are liable for adulteration. A few examples of food adulterants are given below.

Food products	Common adulterants
Milk	Cane sugar, starch, water
Spices and condiments	Sand, colouring matter, paddy husk, lead chromate, saw dust, argemone seed
Oils and fat	Mineral oil, argemone oil, tri-ortho-cresyl phosphate (TOCP), animal fat (tallow) in vegetable fat
Cereals and cereal products	Kesari dhal, colouring matter, talc, inorganic pigments
Beverages	Artificial sweeteners, unpermitted colouring matter, excessive preservatives
Coffee and tea	Cashew nut endocarp, date seed, tamarind seed/ powder, saw dust, added colour
Ice cream	Artificial sweeteners, unpermitted colours like metanil yellow
Synthetic vinegar	Mineral acids
Alcoholic drinks	Methanol, chloral hydrate

In addition to the intentional addition of harmful substance to the food (Adulteration), food contaminants coming into foods like agricultural chemicals (pesticide residues), heavy metals, etc. also need to be monitored.

As a consequence of this public health hazard, a new branch of food chemistry called analytical food chemistry developed essentially to detect adulteration and contaminants. Along side, new legislations to make adulteration unlawful also emerged which greatly expanded efforts by chemists to learn about the native properties of foods, the chemicals commonly used as adulterants and the means of detecting them. You will be learning more on these in subsequent units.

1.4.4 Waste Management

Food processing industries produce huge quantities of wastes – solid and liquid. The liquid wastes (effluents) are loaded with high concentration of sugars and other organic substances. They are quite often discharged into nearby streams. Environmentalists cry foul for justifiable reasons. The Environment Protection Act (EPA) has stipulated various parameters for safe discharge of effluents. This means that the effluent has to be treated suitably to degrade the constituents of the effluents to the safe limits. Therefore, knowledge of the chemical composition of the effluent is vital for designing the effluent treatment protocols.

About 10 to 50 per cent solid wastes are generated while processing food raw materials. They can be in the form of fruit and vegetable peel and pomace, rice husk and bran, milling wastes of other grains and legumes, slaughterhouse wastes and fish processing wastes. The easiest way to dispose them off is to dump them in the nearest land, compost or use them as fuel. A clear knowledge on the chemical composition of the wastes has enabled isolation of by products from them, some of them more valuable than the main product. For example, more than twenty by products are recovered from the peel and pomace of citrus fruits, which brings in more returns to the industry than the citrus juice concentrate, which is the main product. Some of the by products produced are pectin, peel oil, seed meal and oil, candied juice sacks etc. You will be learning more about by product utilization in another unit.

Microbial (also biochemical) conversion of the organic compounds in the wastes to biogas (mostly methane) is another possibility to utilise the food processing wastes. Biogas can be used as fuel.

1.4.5 Societal Roles

As the time progressed, food chemists had to assume greater responsibilities, the most important being involvement in social issues. As already mentioned the developments in food chemistry have created the monster called 'Food Adulteration'. It is the responsibility of the food chemist to contain it. The food chemistry knowledge has also opened up the possibility of using numerous chemicals called food additives to modify or improve the functional properties of foods. Some of them include: antioxidants, emulsifying, stabilizing and anticking agents, and colouring and flavouring agents. Many of the new food products will not have their functional properties without the addition of some of these additives. Their number is continuously increasing. There is considerable fear, often out of ignorance on their use. Food chemists can play the role of educating and advising the public on their usage. Today food chemists are playing a very complimentary role along with the physiologists, microbiologists, nutritionists, food scientists and technologists in providing safe foods to people in the form and place where they wish to have them.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. List a few examples of food adulteration.

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2. Explain with two examples how fruit and vegetable processing wastes can be utilised profitably.

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3. Is there any societal role for a food chemist? If so what is the role?

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1.5 LET US SUM UP

Food chemistry plays a number of important functions in food and nutrition. Some of them include:

- Understanding the chemical nature of food constituents has enabled planning of food formulations suitable for different categories of people.
- Knowledge on the chemical reactions these compounds undergo has helped to control quality changes by developing suitable methods and techniques.
- Food chemistry knowledge assists in food modifications like food fermentations, modified products etc.
- Detects and identifies food adulterants there by ensure food safety.
- Enables proper and profitable management of food processing wastes.
- Advises on judicious use of food additives.

1.6 KEY WORDS

Food chemistry : Study of food constituents, their properties and changes during handling, processing and storage of foods.

Major nutrients : Carbohydrates, proteins and lipids.

Minor nutrients : Vitamins and minerals.

Nutrition labelling : Label of a packaged food product showing the content of its different nutrients per serving.

Nutraceuticals : Bioactive compounds like carotenoids, flavonoids, thiols present in some foods.

Hidden quality : Quality attributes like nutrient content, freedom from adulterants, toxicants that cannot be perceived by the human senses.

EPA : Environment protection act.

Enzymatic changes : Enzyme catalysed chemical reactions.

Biogas : Gas, mostly methane produced by anaerobic fermentation of organic wastes.

1.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - Chemical composition, properties;
   - Chemical changes during storage, processing

2. Your answer should include the following points:

   - Scheele, Lavoisier, Liebig, Thenard

Check Your Progress Exercise 2

1. Your answer should include the following points:

   - Nutrient requirement of human system
   - Nutrient content of different foods
   - Mixing in suitable proportions

2. Your answer should include the following points:

   - Food formulation containing nutrients in required proportion.

3. Your answer should include the following points:

   - Nutrient content per serving

4. Your answer should include the following points:

   - Bioactive compounds
   - Carotenoids
   - Flavonoids
   - Thiols

Check Your Progress Exercise 3

1. Your answer should include the following points:

   - Chlorophyll degradation in spinach and green colour change
   - Pectin degradation and fruit softening

2. Your answer should include the following points:

   - Product factors
   - Environmental factors

3. Your answer should include the following points:

   - Exhausting
   - Nitrogen packing
   - Modified Atmosphere Packaging
   - Controlled Atmosphere storage

Check Your Progress Exercise 4

1. Your answer should include the following points:

   - Starch, sugar, water in milk
   - Paddy husk, saw dust in spices
   - Dates seed, tamarind seed in coffee and tea
   - Mineral acid in vinegar

2. Your answer should include the following points:

   - Pectin, peel oil
   - Biogas

3. Your answer should include the following points:

   - Educating and advising the public on the safe use of food additives.

1.8 SOME USEFUL BOOKS

1. Braverman, J.B.S. (1963) Introduction to the Biochemistry of foods, Elsevier Publishing Company, Amsterdam, London, New York.

2. Meyer L.H. (1969) Food Chemistry, Van Nostrand Reinhold Company, New York, Cincinnati, Toronto, London, Melbourne.

3. Owen R. Fennema (1976) Principles of food science, Part I-Food Chemistry, Marcel Decker Inc.; New York.