FOOD CHEMISRTY I – UNIT I- INTRODUCTION TO FOOD CHEMISTRY

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Dear Students, I welcome you all for our lecture series on FOOD SCIENCE & TECHNOLOGY. In today's lecture, let's make an attempt to know about '**Food Chemistry'.**

Food chemistry is the study of chemical processes of biological and non-biological components of food. The history of food chemistry dates back to 1700s when many chemicals of importance in foods were discovered. Food undergoes numerous changes during the process of handling, processing & storage. Studies in the field of food chemistry focus on food safety, food quality and studies related to flavour, texture, aroma, effect of temperature etc. Food chemistry is intimately related to chemistry, biochemistry, botany, zoology and microbiology. Food chemistry involves the application of chemistry to understand how chemical systems behave in order to control them to improve the nutritional value, safety, and culinary presentation of food. Food chemistry forms the molecular background to understand food in its entirety and its interactions with the human body.

The following aspects will be studied under introduction to food and nutrition:

1. What is Food Chemistry?
2. History of Food Chemistry
3. Components of food
4. Determining the properties of importancein food quality and safety
5. Determining the chemical reactions influencing quality and wholesomeness of foods
6. Cause and effect relationships pertaining to the alteration of food quality and safety during processing
7. Application of Food chemistry

1. What is Food Chemistry?

It is important to understand the definition of food science before learning about food chemistry. Food Science deals with the physical, chemical, and biological properties of foods. Food science is a branch of biological science and an interdisciplinary subject involving primarily microbiology, chemistry, biology, and engineering.

Now let's learn what Food chemistry is?Food chemistry is a major aspect of food science that deals with the composition and properties of food and the chemical changes it undergoes during handling, processing, and storage.Itis the study of chemical processes and interactions of all biological &non-biological components of foods. Food chemistry is intimately related to chemistry, biochemistry, physiological chemistry, botany, zoology, and molecular biology.It is similar to biochemistry in its main components such as carbohydrates, lipids, and protein, but it also includes areas such as water, vitamins, minerals, enzymes, food additives, flavours and colours.

The facts in food chemistryrely on knowledgeof the aforementioned sciences to effectively study and control biological substances as sources of human food. The primary interests in food chemistry include reproduction, growth, and changes that foods and their constituents undergo under suitable/unsuitableenvironmental conditions. This discipline also encompasses how food products change under certain food processing techniques and ways either to enhance or to prevent them from happening. An example of enhancing a process would be to encourage fermentation of dairy products with microorganisms that convert lactose to lactic acid; an example of preventing a process would be stopping the browning on the surface of freshly cut apples using lemon juice.

To the contrary, professionals in food chemistry are concerned primarily with biological substances in food that are dead or dying (postharvest physiology of plants and postmortem physiology of muscle) and changes they undergo when exposed to a wide range of environmental conditions. In addition, food chemistryalso involves the study of chemical properties of disrupted food tissues (flour, fruit and vegetable juices, manufactured foods), single-cell sources of food (eggs and microorganisms), and milk.

In summary, food chemistry has a common aspect with biology, as well as other specific components whichare of utmost importance to mankind.

2. History of Food Chemistry

The 18th and the 19thcenturies were a period of big changes not only in the economy and society,but also in the field of science. Foodscience as a separate science was formed only in the second half of the19th century. The developments in the field of chemistry in this period laid the foundation of food chemistry as a separate branch of science. The French Chemist *Lavoisier*established the fundamental principles of combustion and organic analysis, made the first attempts to determine the elemental composition of alcohol and reported on organic acids of various fruits. *Scheele*, a Swedish pharmacist discovered chlorine, glycerol, isolated citric and malic acid from several fruits.

Liebig in addition to discovery of newer food components perfected the analytical methods, and first classified the foods as either nitrogenous (albumin, casein, animal flesh, and blood) or non-nitrogenous (fats, carbohydrates and alcoholic beverages). He published in 1847, what is apparently the first book on food chemistry entitled '*Researches on Chemistry of Food*'.

Discovery of microorganisms by Louis Pasteur and the knowledge of fermentation processes was a further step in development. Till the end of the 19th century, development of newer chemical analytical methods along with progress in thefield of physiology and nutritionled to the availability of knowledge on the main chemical constituents of foods.

The industrial revolution saw tremendous expansion in many fields, which had a particular bearing on food quality control. This period created many public health problems due to badhygienic conditions, low quality of foods and also adulteration of food. Such a situation led to the establishment of institutions to control chemical composition of foods firstly in Amsterdam, later in many countries in Europe andNorthern America.

The growing importance of food chemistry favoured the establishment of agricultural experimental units, food control laboratories, research institutions, foundation of scientific journals dealing with food chemistry and education of specialists in food chemistry.

3. Composition of food

Food is composed of water, carbohydrates, proteins, lipids known as major components and vitamins, minerals, colorants, flavours, bioactive substances and food additives.

3.1 Water

A major component of food is water, ranging from 50% in meat products to 95% in tomato products. It is also an excellent place for bacterial growth and food spoilage if it is not properly processed. One way of measuring this in food is by analysis of water activity which is very important in the shelf life of many foods during processing. One of the keys to food preservation in most instances is to reduce the amount of water or alter the water's characteristics to enhance the shelf-life. Such methods include dehydration, freezing, and refrigeration.

3.2 Carbohydrates

A carbohydrate is a biological molecule consisting of carbon (C), hydrogen (H) and oxygen (O) atoms. The simplest version of a carbohydrate is a monosaccharide which possesses the properties of carbon, hydrogen, and oxygen in a 1:2:1 ratio under a general formula of CnH2nOn where n is a minimum of 3. Glucose is an example of a monosaccharide and also fructose. A chain of monosaccharides form to make a polysaccharide. Such polysaccharides include pectin, dextran, agar, and xanthan.

3.3 Proteins

Proteins are macromolecules consisting of one or more long chains of amino acid residues.They also play a fundamental role in the structure and function of cells. Consisting mainly of carbon, nitrogen, hydrogen, oxygen, and some sulphur, they also may contain iron, copper, phosphorus, or zinc.Food proteins may be defined as those that are easily digestible, nontoxic, nutritionally adequate,functionally useable in the food products, available in abundance, and sustainable agriculturally.Protein is commonly obtained from animal sources: eggs, milk, and meat. Nuts, grains and legumes provide vegetable sources of protein, and protein combining of vegetable sources is used to achieve complete protein nutritional quotas from vegetables.

3.4 Lipids

The term lipid comprises a diverse range of molecules and includes relatively water-insoluble or nonpolar compounds of biological origin, including waxes, fatty acids (including essential fatty acids), fatty-acid derived phospholipids, sphingolipids, glycolipids and terpenoids such as retinoids and steroids. Some lipids are linear aliphatic molecules, while

others have ring structures. Some are aromatic, while others are not. Some are flexible, while others are rigid.

Most lipids have some polar character in addition to being largely nonpolar. Generally, the bulk of their structure is nonpolar or hydrophobic ("water-fearing"), meaning that it does not interact well with polar solvents like water. Another part of their structure is polar or hydrophilic ("water-loving") and will tend to associate with polar solvents like water. This makes them amphiphilic molecules (having both hydrophobic and hydrophilic portions). Lipids in food include the oils of such grains as corn, soybean, from animal fats, and are parts of many foods such as milk, cheese, and meat.

3.5 Vitamins

Vitamins are organic compounds which are vital nutrients required in small amounts for essential metabolic reactions in the body. These are broken down in nutrition as either water-soluble (Vitamin C) or fat-soluble (Vitamin E).Vitamins are necessary for normal growth and good health of an individual and shortage of one or more vitamins in the body results in deficiency diseases in the individual.From a food chemistry point of view several of the vitamins influence the chemical nature of food, by functioning as reducing agents, radical scavengers, reactants in browning reactions, and as flavour precursors. The main interest of food chemistry is to maximize the retention of vitamins in food.

3.6 Minerals

Minerals in foods are naturally occurring inorganic substances that are large and diverse with many of them required for the normal functioning of the body.Mineral elements are present in foods in many different chemical forms. These forms are commonly referred to as *species* and include compounds, complexes, and free ions. Mineralsarepresent in low concentrations in foods compared to carbon, hydrogen, oxygen and nitrogen. Nonetheless, they play key functional roles in both living systems and foods. Minerals are found in foods such as meat, cereals (including cereal products such as bread), fish, milk and dairy foods, vegetables, fruit (especially dried fruit) and nuts.

3.7 Enzymes

Enzymes are biochemical catalysts used in converting processes from one substance to another. They are also involved in reducing the amount of time and energy required to

complete a chemical process. Many aspects of the food industry use catalysts, including baking, brewing, dairy, and fruit juices, to make cheese, beer, and bread.

3.8 Colour

Food colouring is added to change the colour of any food substance. It is mainly for sensory analysis purposes. It can be used to simulate the natural colour of a product as perceived by the customer, such as red dye used in ketchup. Caramel is a natural food dye; the industrial form known as‘caramel colouring’ is the most widely used food colouring and is found in foods from soft drinks to soy sauce, bread, and pickles.

3.9 Flavours

Flavour in food is important in how food smells and tastes to the consumer, especially in sensory analysis. Some of these products occur naturally like salt and sugar, but flavour chemists develop many of these flavours for food products. On such artificial flavours include lactic acid which gives milk a tart taste.

3.10 Food additives

Food additives are substances added to food for preserving flavours, or improving taste or appearance. The processes are as old as adding vinegar for pickling or as an emulsifier for emulsion mixtures like mayonnaise. These are generally listed by "E number" in the European Union or GRAS ("generally recognized as safe") by the United States Food and Drug Administration.

The analysis of chemistry of foods includes the following major aspects-

4.Determining the properties of importance in food quality and safety

Safety is the first requisite of any food. In a broad sense, this means a food must be free of any harmful chemical or microbial contaminant at the time of its consumption. Steps taken to prevent microbial growth may or may not interfere with other quality attributes of food. A list of quality of foods and potential alterations that can occur during processing and storage is presented in table no1.

Table no 1. Alterations that can occur in quality attributes of food during processing and storage

Attribute	Alteration
Texture	• Loss of solubility • Loss of water-holding capacity • Toughening • Softening
Flavour	• Development of rancidity (hydrolytic or oxidative) • Cooked or caramel flavours • Other off-flavours • Desirable flavours
Colour	• Darkening • Bleaching • Development of desirable colors (e.g., browning of baked goods)
Nutritive Value	• Loss, degradation, or altered bioavailability of proteins, lipids, vitamins, minerals, and otherhealth-promoting components
Safety	• Generation of toxic substances • Development of substances that are protective to health • Inactivation of toxic substances
Source: Damodaran, S., Parkin, K. L., &Fennema, O. R. (Eds.). (2007). *Fennema's food chemistry*. CRC press.	

5. Determining the chemical reactions influencing quality and wholesomeness of foods

Many chemical and biochemical reactions can alter the food quality and safety. Some of the moreimportant classes of these reactions are listed in Table no 2. Each reaction can involve different substrates depending on the specific food and the conditions of handling,processing or storage. These reactions occur due to the general nature of the substrates present in foods and not limited to individual foods.

For instance, non-enzymatic browning involves reaction of carbonyl compounds, which can arise from existing reducing sugars or from diverse reactions, such as oxidationof ascorbic acid, hydrolysis of starch, or oxidation of lipids. Oxidation may involve lipids, proteins, vitamins, or pigments, and more specifically, oxidation of lipids may involve triacylglycerols in one food or phospholipids in another.

Table no 2. Some Chemical and Biochemical Reactions leading to alteration of food quality or safety

Types of Reaction	Examples
➢ Non-enzymatic browning	➢ Baked goods, dry, and intermediate moisture foods
➢ Enzymatic browning	➢ Cut fruits and some vegetables
➢ Oxidation	➢ Lipids (off-flavours), vitamin degradation, pigment decoloration, proteins (loss of nutritive value)
➢ Hydrolysis	➢ Lipids, proteins, vitamins, carbohydrates, pigments
➢ Metal interactions	➢ Complexation (anthocyanins), loss of Magnesium from chlorophyll, catalysis of oxidation
➢ Lipid isomerization	➢ cis → trans isomerization, non-conjugated → conjugated
➢ Lipid cyclization	➢ Monocyclic fatty acids
➢ Lipid oxidation–polymerization	➢ Foaming during deep-fat frying
➢ Protein denaturation	➢ Egg white coagulation, enzyme inactivation
➢ Protein crosslinking	➢ Loss of nutritive value during alkali processing
➢ Polysaccharide degradation	➢ In plants postharvest
➢ Glycolytic changes	➢ Animal postmortem, plant tissue postharvest
Source: Damodaran, S., Parkin, K. L., &Fennema, O. R. (Eds.). (2007). Fennema's food chemistry. CRC press.	

6. **Cause and effect relationships pertaining to alteration offood quality and safety during processing**

We have learnt about the attributes of food and possible alterations in them.Now let's learnabout the causes of such a change. The changes in foods comprises of a series of primary events followed by secondary events, which inturn become evident as altered attributes of a food. A single quality attribute can be altered as a result of several different primary events. Such examples of primary and secondary events and their respective effect on the quality attributes are presented in Table no 3.

The sequence of events can be understood in two directions. One by considering a primary event followed by the associated secondary event and the effect on a quality attribute. Another is by considering the observed change in the attribute and then determining all the probable primary events leading to such a change followed by isolation of the particular event by appropriate chemical tests. Construction of such sequences encourages implementation of analytical approach in assessing food alterations.

Table no 3.Primary and secondary events leading to alterations in food quality attributes

Primary causative event	**Secondary events**	**Quality attributes influenced**
Hydrolysis of lipids	Free fatty acids react with protein	Texture, flavour and nutritive value
Hydrolysis of polysaccharides	Reaction of sugars with protein	Texture, flavour, colour and nutritive value
Oxidation of lipids	Reaction of oxidative products with many constituents	Texture, flavour, colour and nutritive value
Bruising of fruit	Damage to cell membranes Release of enzymes	Texture, flavour, colour and nutritive value
Heating of food products	Loss of integrity of cell walls and membranes Release of acids and inactivity of enzymes	Texture, flavour, colour and nutritive value
Heating of muscle tissue	Denaturation of protein Inactivation of enzymes	Texture, flavour, colour and nutritive value
Source: Damodaran, S., Parkin, K. L., &Fennema, O. R. (Eds.). (2007). Fennema's food chemistry. CRC press.		

7. **Applications of Food Chemistry**

Food chemistry uses analytical techniques to study the chemical components of food items in other to detect the nutritional and non-nutritional compounds. Knowledge of the nutritional value of food is essential for developing a food product with essential

nutrients.Food chemistry helps in transformation of food into nutritious, safe and materials of commercial value.Varieties of flavours, preservatives, emulsifiers, thickeners, stabilizers, sweeteners and colours are some of the materials that are produced as a result of application of food chemistry.Food chemistry is credited for the birth of numerous natural and artificial food preservatives. The study of some conventional preservation methods has resulted in the synthesis of industrial food preservatives.

Research in the field of food chemistry has led to the design and development of new food products for industries. The study of the component of various food substances are used to initiate an array of chemical reactions leading to the formation of either new or improved food products. The improvement could be taste enhancement, new aroma, colour, or increased shelf life.

8. Conclusion

The science of food chemistry is important in making the food we eat as safe, nutritious and appealing from the production area through the processing and handling stages till we consume them. It is an integrated subject involving application of knowledge fromvarious other related subjects such as Chemistry, Botany, Microbiology and Engineering. The main objective is to understand the innate properties of food components, their interactions with the environment right from processing, storage, handling and manipulating them favourably for human use. Thus food chemistry is a major aspect of food science dealing with the chemical properties of food components as they relate to stability, cost, quality, processing, nutritive value, wholesomeness and convenience.