

**COURSE CODE:** FST 309  
**COURSE TITLE:** BASIC FOOD CHEMISTRY  
**COURSE UNIT:** 3 UNITS  
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## **LECTURE I - INTRODUCTION**

### **1.0 HISTORICAL BACKGROUND**

- Accidental discoveries of processes and attempt to control man's environment.
- Passage of Food and Drug Act by the United States (U.S) congress (1906) catalysed by the study of food chemistry.
- First official document of AOAC (Official methods of Analysis of the Association of Official Agricultural Chemists) in 1955.
- Food Chemistry today.

### **1.1 DEFINITION OF FOOD CHEMISTRY**

- The study of composition of foods and of the reactions which lead to changes in their constitution and characteristics.

### **1.2 BENEFITS DERIVABLE FROM THE STUDY OF FOOD CHEMISTRY**

- Basic knowledge of the constituents of food.
- Determination of appropriate processing and preservation method.
- Aids understanding of microbiological reactions in food.
- Information on chemical reactions involving food.
- Useful information in New Food Product Development
- Useful information to Engineers in design and fabrication of appropriate food processing equipment.
- Help in choice of packaging material, equipment and technique.
- Useful in storage stability and shelf life studies of food and food products.

## **LECTURE 2**

### **2.0 WATER IN FOODS**

- Water as basic constituent of ALL foods.

### **2.1 FORMS OF WATER IN FOOD**

- Free water/moisture

- Hydrates of water
- Imbibes water
- Adsorbed water

## 2.2 **PROPERTIES OF WATER**

- Structure and Bonds in water H<sub>2</sub>O, covalent and H-bonds.
- Some physical properties of water and ice.
  - \* Density
  - \* Vapour pressure
  - \* Refractive index
  - \* Viscosity
  - \* Specific heat
  - \* Heat of vapourization
  - \* Thermal conductivity
  - \* Dielectric constant
  - \* Coefficient of thermal expansion
  - \* Melting point
  - \* Boiling point.

## 2.3 **WATER ACTIVITY**

- The concept of water activity relates the moisture (water) in a food to the RH of the air surrounding the food and is defined as ratio of the partial pressure of water in a food to the vapour pressure of water at the same temperature.

$$a_w = p/p_o \text{ where } P = \text{vapour pressure of water in food}$$

$$P_o = \text{vapour pressure of pure water at the same temperature}$$

$$a_w = \text{Water Activity.}$$

OR  $a_w$  can be defined as the ratio of the vapour pressure of water in a food to the saturated vapour pressure of water at the same temperature.

i.e.  $P/P_o$  where  $P$  (pa) = Vapour pressure of water in food

$$P_o = \text{Vapour pressure of pure water at the same temperature.}$$

$$a_w = \text{water activity}$$

- for pure water  $a_w = 1.0$
- High m.c. amount of moisture > that of solids,  $a_w \leq 1.0$
- Adsorption process

Dry product subjected to increasing moisture levels in the surrounding/Environment.

- Desorption process  
Moist product gradually equilibrating with lower moisture levels of the surrounding/environment.
- Hysteresis loop
  - Difference between adsorption and desorption isotherms.
  - It occurs because adsorption and desorption isotherms are more identical.

## 2.4 **WATER ACTIVITY AND FOOD SPOILAGE**

- Moisture content and  $a_w$  are important factors which affect ratio of spoilage of food in terms of chemical, biochemical and microbiological reaction.
- for M.c 5-15% - moist, dried foods (powdered) - Great storage stability
- M.C. 20-40% - Intermediate moisture foods - less stable than dried foods.

### 2.4.1 **Biochemical/Chemical Reactions Attached By $a_w$**

- Most Enzymes are inactivated when  $a_w < 0.85$  e.g. Amylases, peroxidases etc
- Lipases are still active at  $a_w$  0.3 or less.
- Maillard reactions occur at  $a_w$  0.6 – 0.7.

### 2.4.2 **Microbiological reactions**

- Bacterial growth – Impossible at  $a_w < 0.90$
- Molds and yeasts – Inhibited between  $a_w$  0.88 – 0.80
- Osmophilic yeasts can grow at  $a_w$  of 0.65

## **LECTURE 3**

### 3.0 **PROTEINS**

- Complex organic substances present in all living matter (plants, animals and microorganisms).
- ALL proteins, apart from consisting of C, H and O also contains N and sometimes may contain S as well as P.

### 3.1 AMINO ACID

- Structural units of all proteins are amino acids. General formula  $\text{RCN}(\text{NH}_2)\text{COOH}$ .
- There are 200 such amino acids.
  - \* Aliphatic monomeric monocarboxylic amino acids Glycine, Alanine, Valine, Leucine, Isoleucine, Serine, Threonine and Proline.
  - \* Sulphure containing amino acids. Cysteine cystine & methionine.
  - \* Mono amino Dicarboxylic amino acids. Aspartic acid and glutamic acid.
  - \* Basic Amino acids.  
Lysine, Arginine and Histidine
  - \* Aromatic amino acids.  
Phenyl alanine, tyrosine and Tryptophan
  - \* Derivatives of other amino acids  
4 – Hydroproline and 5-Hydrolysine.

#### 3.1.1 Properties of Amino acids

- Optical Activity
- Zwitterion formation (Electrostatically neutral form).
- Isoelectric point –pH at which the amino acid consist of mainly Zwitterion e.g. for Glycine  $\text{pH}_i = 5.97$

### 3.2 CLASSIFICATION OF PROTEINS

- can be based on solubility, coagulation or prosthetic groups.
- Simple proteins  
proteins that will yield only amino acids on hydrolysis e.g. Albumins, globulins, colutelins, protamines etc.
- Complex proteins  
Proteins that contains non-protein entities attached to the polypeptide chain e.g. phosphoproteins, Glycoproteins, Lipoproteins, Chromoproteins, Nucleoproteins etc.

#### 3.2.1 Properties of Proteins

- Amphoterism
- Solubility
- Colour Reactions e.g. Biuret reaction

- Hydrolysis using 6 mHCL, or 5MN<sub>a</sub>OH or action of proteolytic enzymes.
- Oxidation Reduction reaction
- Sensory characteristics – Tasteless, odourless and Colourless.
- Molecular weight – they are High Mw cpds.  
e.g. Insulin – 5,700, Myosin – 620,000 Ribonuclease – 12,000.
- Structure of proteins – are joined by (prh) peptide bonds.
  - \* primary eg mw, aa composition and linear sequence of the aa residues along the polypeptide chain.
  - \* Conformation:
    - Secondary structure
    - Tertiary structure
    - Quaternary structure

### 3.2.2 **Protein Denaturation**

Term used to describe changes in the physico-chemical properties of soluble proteins. It can be described as any modification in the conformation of a protein.

- Factors that can cause protein Denaturation.
  - Heat
  - Strong acids (low pH)
  - Strong bases (High pH)
  - Some solvents such as ethanol
  - Conc solution of salts
  - Phenolic substances.
- Changes that may accompany denaturation
  - Coagulation (Loss of solubility)
  - Gel formation
  - Higher Digestibility (Higher susceptibility to Enzyme hydrolysis)
- Renaturation  
Reverse of denaturation (slow and practically irreversible).
- Application
  - Denaturation of Enzymes e.g. Blanching of fruit and vegetables.  
Pasteurization of milk etc.

- Preparation of cheese – Acidification of milk proteins souring of milk (yoghurt)
- Flavour and texture modification through exposure of – SG groups eg Eggs, meta/wheat proteins.

## LECTURE 4

### 4.0 BROWNING REACTIONS

Complex reactions which occur in food leading to formation of brown colour. It could be as a result of processing or storage of food. Two main types:

- Enzymic Browning
- Non-Enzymic

### 4.1 ENZYMIC BROWNING OF FOODS

Browning catalysed by enzyme, it occurs in the

- Presence of oxygen
- Phenolase Enzyme (or Polyphenol oxidases)
- Enzyme activity can be divided into 2:
  - The cresolase activity
  - The catecholase activity.
- Characteristics:
  - The enzymes are copper proteins and they are active in the monovalent form of copper.
  - pH of activity near 7
  - Fairly resistant to heat.
- Specificity of the Enzyme
  - Acts on monophenol or ortho-diphenol not on meta-diphenol.
- Reactions:
  - Crisolate activity – It acts as oxygen transferable in the hydrogenation of monophenol to polyphenol derivatives. Eg. Tyrosine – 3, 4 – dihydroxy phenyl Alamine (DOPA).
  - Catecholase activity.

Acts as a dehydrogenase enzyme in removing Hydrogen from substances.

DOSA – O. quinine phenyl Alamine,

- The quinine then forms DOPAchrome which polymerises to form melanin.

- Application:

Common during processing of vegetable tissues that rich in polyphenols e.g yam.

#### 4.1.2 **Control of Enzymic Browning**

Aim – To stop activity of phenolase enzyme.

Methods:

- Heat treatment e.g. Blanching
- Use of SO<sub>2</sub> – It inhibits phenolase enzyme.
- Use of acids.  
Eg. Ascorbic acid  
other acids e.g. Citric, Malic
- Removal of surface oxygen
- Use of salts e.g. Nacl solution
- Other methods e.g. Borate salts, HCN etc. Some of these may not be applicable to food because of some other effects e.g HCN in poisonous, boric/Borate salt may colour the food etc.

## LECTURE 5

### 5.0 **NON-ENZYMIC BROWNING OF FOODS**

Browning that is not catalysed by enzyme. Three types exists:

- Maillard Reaction
- Caramelization
- Ascorbic Acid browning

#### 5.1 **MAILLARD REACTION**

This type of browning involves reaction between sugars and amino acids (proteins). It occurs at high temperature. The reactions involved can be divided into 5 main steps:

- Condensation of sugars with amino compound.

- Rearrangement of condensation products (Amadori-rearrangement)
- Dehydration of rearrangement products leading to formation of furfural or its derivative (HMF).
- Degradation and fission reaction
- Polymerization of the products of degradation and fission into melanin/melanolin

#### 5.1.1 **Application**

- Browning during food processing such as baking of bread, roasting of

#### 5.2 **ASCORBIC ACID BROWNING**

Non enzymic browning phenomenon associated units fruit juices and concentrated especially discolouration of citrus products.

- Ascorbic acid browning can occur in the presence or absence of amino acids.
- Although mechanism of reaction is not very clear, it involves oxidation of Ascorbic acid in the presence of air to dehydroascorbic acid and subsequently to 2, 3-diketogulonic acid.
- The presence of oxygen tends to intensify colour formation until it reaches a maximum and then colour formation decreases in the presence of excess oxygen as if oxygen had a bleaching effect on the pigment formed.
- Among the intermediates identified:
  - furfural
  - 2-furoic acid
  - Threonic acid
  - Oxalic acid
  - L-erythro-pentosulose
  - Carbon dioxide

#### 5.3 **CARAMELIZATION**

- Browning reactions of sugars in the absence of amino acids and at high temperatures >100°C. This temperature is higher than temperatures at which maillard reactions occur. It is otherwise called pyrolysis of sugars.
- Pyrolysis usually lead to formation of brown colour and characteristic flavours.
- It may be intentional or incidental during food processing.
- Catalysts.



Caramelization is catalysed by phosphates, alkalis, acids and salts of carboxylic acids of citrate, fumarate, tartarate and malate.

- Mechanism of reaction not totally clear but may be similar to that of sugar-amino browning and could involve:
    - Enolization
    - Dehydration
    - Fission
- Leading to formation of Hydroxy-                      furfural (HMF).

#### 5.4 **NUTRITIONAL EFFECT OF BROWNING**

- Irreversible binding of amino acids into complex pigments
- Destruction of amino acids through strecker degradation.

#### 5.5 **PRACTICAL PREVENTION OF BBROWNING**

- Refrigeration
- Use of chemicals e.g. SO<sub>2</sub>
- Low pH
- Lowering concentration
- Use of sucrose
- Fermentation

## **LECTURE 6**

### 6.0 **LIPIDS**

Lipids are natural substances which are insoluble in water, but soluble in non-polar solvents such as hexane, benzene, carbon tetrachloride, ether etc. Chemically, they can be described as actual or potential derivatives of fatty acids or closely related substances.

#### 6.1 **CLASSIFICATION**

- Simple lipids
- Composite lipids
- Sphingo lipids

- Derived lipids

## 6.2 SIMPLE LIPIDS

- Glyceryl esters

They are formed as a result of esterification of glycerol molecule with fatty acid units. They can be:

- Monoglyceride – glycerol + 1 Fatty acid
- Diglyceride - glycerol + 2 fatty acid
- Triglyceride - glycerol + 3 fatty acid

Most natural fats and oils are Triglycerides (TC<sub>a</sub>)

If the TC<sub>a</sub> exists as solid at room temperature it is a FAT

If the TC<sub>a</sub> exists as liquid at room temperature it is an OIL

### 6.2.1 FATTY ACIDS

Aliphatic carboxylic acids. They can be divided into 2 main types:

- Saturated fatty acid (No double bond)
- Unsaturated fatty acid (Double bond present)
- Saturated fatty acids – are homologous series with a general formula and gradation in properties (physical and chemical) e.g. Butyric acid, caproic acid etc.
- Unsaturated fatty acids makes up the fatty acids contained in majority of oils from plant sources e.g. oleic acids, Linoleic acid, etc.
- Glyceryl resters can be simple or mixed TC<sub>a</sub>  
Simple TC<sub>a</sub> have all the 3 fatty acid units the same.  
Mixed TC<sub>a</sub> have all the 3 fatty acid units different.
- Most natural fats and oils are mixed TC<sub>a</sub>

## 6.3 PROPERTIES OF TRIGLYCERIDES

### 6.3.1 Physical properties

- Colourless, odourless, tasteless and water  
Insoluble – melting point – Refractive index
- Plasticity – Specific gravity – smoke, flash and fire prints etc.

### 6.3.2 Chemical properties

- Hydrolysis (Saponification)
- Oxidation (Antioxidation)
- Iodine value
- Acid/free fatty acid value etc.

## LECTURE 7

### 7.0 LIPID OXIDATION

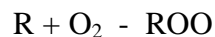
- Rancidity – Occurrence of off-flavours in fat containing foods.
- Antioxidation-spontaneous oxidation of a substance in contact with molecular oxygen.
- Consequences of lipid autoxidation.
  - Rancidity
  - Colour changes accelerated through browning reactions.
  - Impaired nutritional value of food
  - Toxicity
- Part most affected by lipid autoxidation is the unsaturated fatty acids and this becomes more pronounced as the number of double bonds increases.

### 7.1 MECHANISM OF REACTION

Step 1; Initiation



Step 2: Propagation



Step 3: Decomposition



Step 4: Termination



#### Activation

Note: The methylenic groups adjacent to a double bond of a fatty acid is particularly labile.

Eg. oleic

**Exercise:** find how many free radicals may be formed by linoleic and Linolenic acids

## 7.2 RATE OF ANTOXIDATION

- (i) Rate of O<sub>2</sub> consumption (O<sub>2</sub> uptake)  
OR
- (ii) Accommodation of peroxides (rep by            value) (PV)
- (iii) OR determination of decomposition products (in form of oxidized fat)
- (iv) Other methods – organoleptic tests.

## 7.3 EFFECTS OF ENVIRONMENTAL FACTORS

- Temperature in Q10 values for chemical reaction  
Affects rate of antioxidation and reaction mechanization
- Light- UV light is potent than white light
- Oxygen – without O<sub>2</sub> reaction mechanism  
Stage 2 (            ) will be
- Moisture – Intermediate moisture (monolayer            values) are more stable than either low or high m.c (released to air).
- Ionizing radiation e.g High energy rays (B &            rays)  
(radiation induced free-radicals) may affect even saturated fats
- Catalysts
  - Metal catalysts – (ions of
  - Naturally
  - Enzymes (Li
- Antioxidants (oxidation)  
Naturally