

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 H₂O, 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 and 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 M HCl, or 5 M NaOH 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 Alanine (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 SO₂ – 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 **CARMELIZATION**

- Browning reactions of sugars in the absence of amino acids and at high temperatures $>100^{\circ}\text{C}$. 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. SO₂
- 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_a)

If the TC_a exists as solid at room temperature it is a FAT

If the TC_a 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_a
Simple TC_a have all the 3 fatty acid units the same.
Mixed TC_a have all the 3 fatty acid units different.
- Most natural fats and oils are mixed TC_a

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

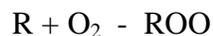
- Rancidity – Occurrence of off-flavours in fat containing foods.
- Antioxidation-spontaneous oxidation of a substance in contact with molecular oxygen.
- Consequences of lipid autoxidation.
 - Rancidity
 - Colour changes accelerated through browning reactions.
 - Impaired nutritional value of food
 - 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 O₂ consumption (O₂ 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 O₂ 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