THE ROLE OF CHEMISTRY IN FOOD PRODUCT DEVELOPMENT

delivered by

MR. CHRISTOPHER C OFUANI, M.Sc. fsi

DEPUTY DIRECTOR, FOOD REGISTRATION DIVISION, REGISTRATION & REGULATORY AFFAIRS DIRECTORATE, NAFDAC

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The Departmental Town & Gown Seminar Series

OF **THE CHEMISTRY DEPARTMENT** OF

COVENANT UNIVERSITY, **OTA,** ON 10TH FEBRUARY 2016

SCOPE OF PRESENTATION.

- Conceptual clarification
- Basic structure of food
- Chemical Interactions of food components
- Nutritional impacts

Additives/JECFA

- Conclusion.

CONCEPTS

- In this presentation, chemistry refers to “food chemistry” a key area of food science which is intimately related to chemistry, biochemistry, molecular biology and other biological sciences.
- Food chemistry deals with the composition and properties of food and the chemical changes it undergoes during handling, processing, and storage.

Concepts cont’d

- Food, any item ingested for nutrition and physiological growth, will include ingredients used in food production but does not include medicines, tobacco and live animals.

Concepts cont’d

- Product development is a process in which new food product ideas are generated and the products are created and marketed. It involves the conceptualization, formulation, processing , testing and marketing of new products. Modifying existing products for better quality is also part of product development.

Concepts cont’d.

- Chemistry is key to understanding food science principles. All the changes that occur during processing affect the chemical composition of foods.
- Food chemistry provides the basic knowledge for the conversion of these changes into new product development.

Concepts cont’d

- These changes are studied by product development specialists before their incorporation into commercial processes to produce new food products.
- Monitoring these changes is the work of quality assurance/ control personnel

Concept cont’d

- With the knowledge of the reactions and the factors that lead to alterations in texture, color, flavor, nutritive value and food safety, food scientists are able to control these alterations to produce the desired food products.

Concepts cont’d

- With a strong knowledge base a food company is able to secure its share of the market while reducing the time between product development and introduction of new products in the market.

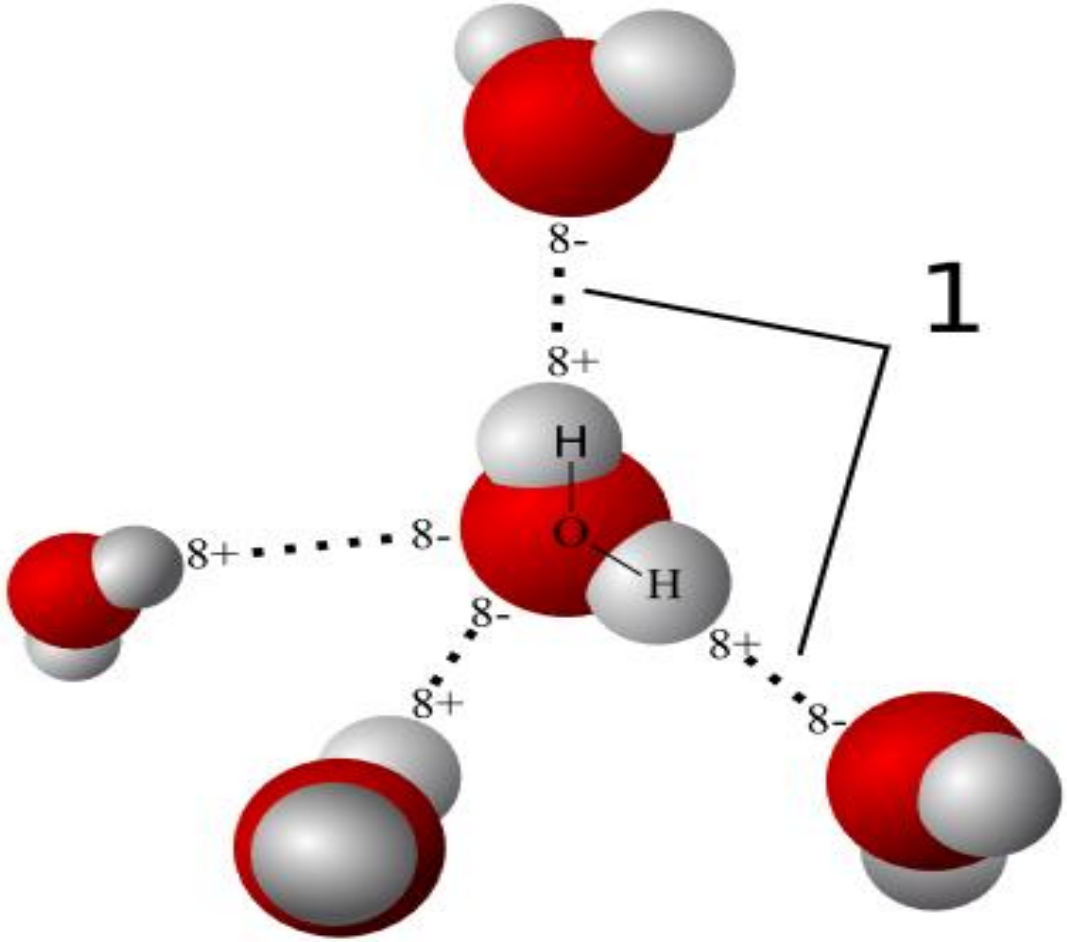
Main Components of foods

- The main components of most foods are water, carbohydrates, lipids, proteins, fiber, organic acids and mineral compounds in various proportions.
- Foods also contain many other minor constituents and additives
- Why are these components reactive?

Main components of foods

- **Water**
- A major component of food and exists in different forms.
- Water in food is described as moisture content or water activity
- Has unique properties; high melting and boiling points
- Ability to dissolve ionic substances
- Acts as diluent and carries hydrophilic food ingredients
- Provides a medium for chemical and enzymatic reactions

Model of Hydrogen bonds (1) between water molecules



THE ROLE OF CHEMISTRY IN FOOD PRODUCT DEVELOPMENT

- Acts as a fat replacer and zero calorie ingredient
- Accounts for food moisture, a component of gels and emulsions
- A medium for heat transfer
- A reactant or product in chemical reactions (in condensation and hydrolysis)

THE ROLE OF CHEMISTRY IN FOOD PRODUCT DEVELOPMENT

- Water activity is a measure of the unbound, free water in a system available to support biological, enzymatic and chemical reactions.

  - Water activity, $A_w = \frac{P}{P_O}$

    Po = is vapor pressure of water and
    P is vapor pressure of the food.
    This is equal to the mole fraction of pure water in the solution , which is equivalent to the number of moles of water in the solution divided by the **total** number of moles present

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- Water activity (A_w) is an important parameter in achieving food product stability through the control of microbiological and chemical activities. It is used by regulators as a parameter for food safety ($A_w < 0.85$)
- As pH indicates the degree of acidity in a food so does A_w indicates the degree of available water. In general, the water activity of a food that is highly perishable has a value close to that of clean water , which is 1.

Water activity cont’d

- .Water activity plays a critical role in most of the changes that occur in food systems such as browning, lipid oxidation and enzymatic reactions
- Controlling water and limiting its availability for microbiological, chemical and physical transitions is an important task in achieving the desired food product stability

THE ROLE OF CHEMISTRY IN FOOD PRODUCT DEVELOPMENT

• REACTIVE GROUPS IN FOOD

• **REACTIVE GROUPS**	**SOURCES**
• - SH, -S-S-	Proteins, peptides and amino acids
• $-NH_2$, -NH-C (=NH)NH_2	Proteins, amino acids and other amine containing compounds
• -OH, -CHO, $R_2C=O$	Proteins, carbohydrates and low molecular weight carbonyls
• O_2, $^*O_2$-, $^*OH$, H_2O_2, RO^*, ROO^*, ArO^*, $ArOO^*$	Products of lipid oxidation
• COOH, -O-SO_3H, -O-PO_3H_2	Proteins, pectins and other polysaccharides
• -CH=CH-, -CH=CH-CH_2	Unsaturated lipids.

Main components and their reactive parts.

The major macronutrients of food have functional groups.

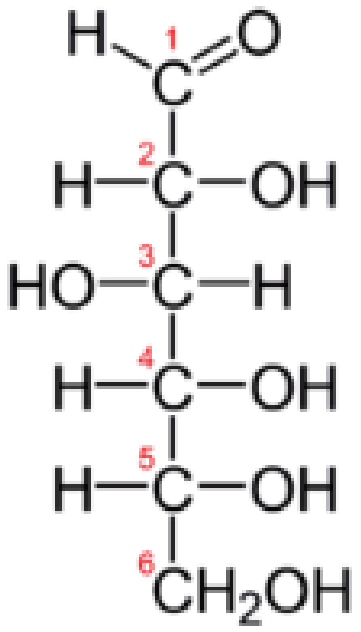
These functional groups represent their structural features as well as their reactive sites.

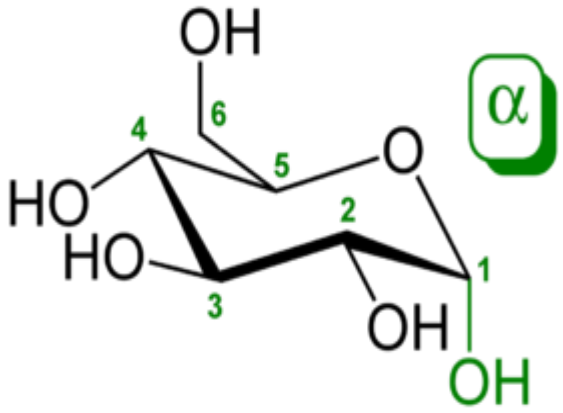
In carbohydrates, -C=O carbonyl groups in reducing sugars and the –OH alcohol group; in fats and lipids, the presence of double bonds and in proteins, the amide, sulfhydryl groups, all play key roles in most of the reactions.

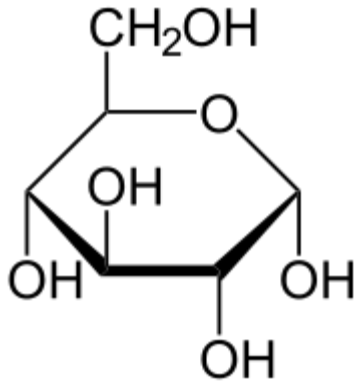
Major macronutrients and features.

- CARBOHYDRATES: $C_x (H_2O)_y$
- Monosaccharides are carbohydrate molecules that cannot be broken down to simpler carbohydrate molecules by hydrolysis, so they are referred to as simple sugars. They are the monomeric carbohydrates
- They are the building blocks for disaccharides, oligosaccharides and polysaccharides.
- Sugars that contain the aldehyde or ketone carbonyl group are called reducing sugars.

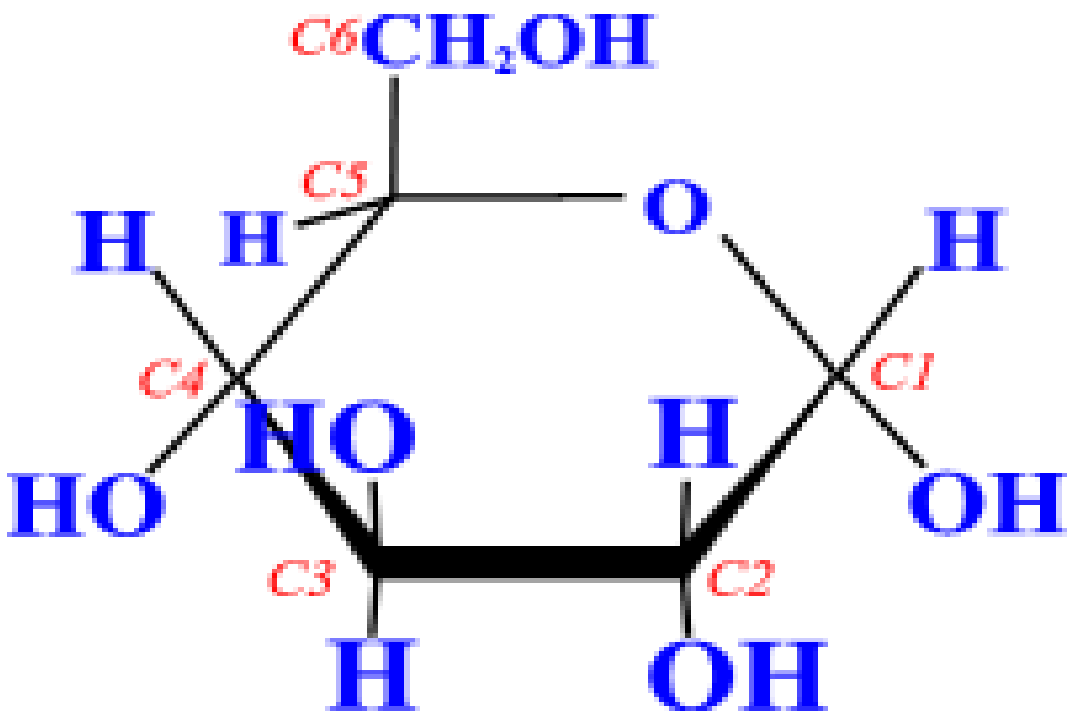
Glucose in three different structural forms, Fisher, (chair)glucopyranose & Haworth's projection







Numbering of carbon atoms in glucose



Browning of foods

- There are two types of browning of foods. Oxidative and non -browning.
- Oxidative browning does not involve reducing sugars. It is a reaction between oxygen and a phenolic substrate present in the food, catalyzed by the enzyme polyphenolic oxidase. This occurs in apples , bananas, pears when we cut or bite into them.

Non-oxidative browning

- There are two types of non oxidative browning and they are very important in foods. Caramelization and Maillard reaction.
- Caramelization is the formation of brown colors as a result of applying heat to sugars. Temperature of > 200^{o}C
- There are different types of caramels which are used to impact color and flavor in beverages and bakery products.

Non-oxidative browning cont'd

- Maillard reaction takes place in the presence of a reducing sugar, water and an amino bearing compound such as protein or amino acid. The sequence of reactions are as follows:

a. Reducing sugar + amino group ⟶ glycosylamine

b. Glycosylamine ⟶ Amadori compounds ⟶ pyrazines

c. Polymerization; Colorless intermediate ⟶ brown pigments

Browning cont’d

- Browning reactions yield a variety of volatile compounds, these are responsible for the specific flavors of heated foods e:g roasting of peanuts and coffee.
- Volatile flavorants produced in amino-sugar reactions are mainly pyridines, pyrazines, imidazole and pyrroles. The aroma produced in such reactions changes with increasing temperatures. However, the development of low molecular weight volatiles must be controlled.

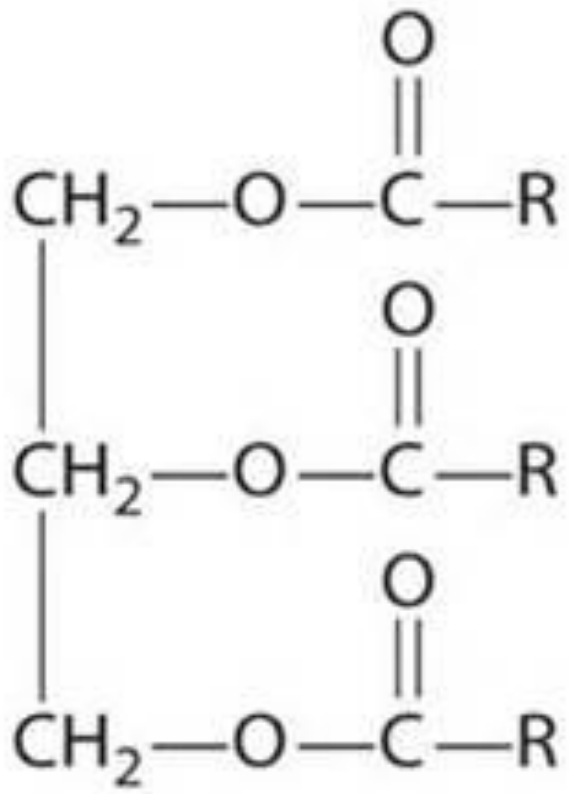
Non oxidative browning cont’d

- The most important saccharides participating in the Maillard reactions are glucose and fructose, while in meat it may be ribose. Among disaccharides, lactose is an important browning precursor in dairy products as is maltose in cereal products, such as malt.
- Sucrose is easily cleaved into glucose and fructose, especially on heating. Therefore, it can participate in non-enzymatic browning quite easily. Sugars bound as glycosides, for example, in glycoproteins, glycolipids, and in heteroglycosides are less reactive,

LIPIDS

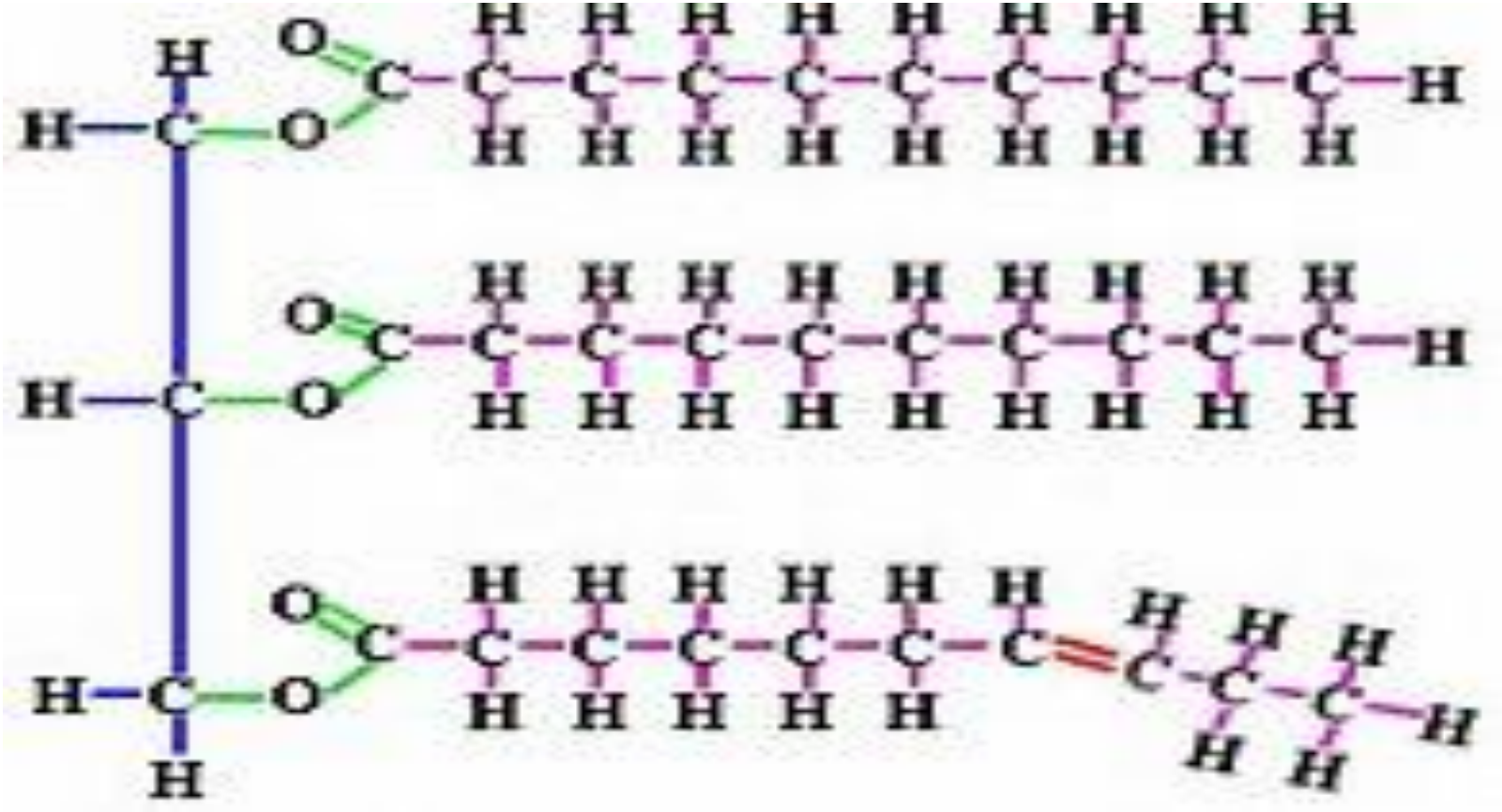
- Mainly non polar organic substances, slightly soluble in water depending on structure. Lipids are classified as simple, compound or derived lipids.
- Simple lipids : esters of fatty acids with glycerol
- Compound lipids: in addition to fatty acids contain other compound such as phosphate or carbohydrate. Have polar tendencies.
- Derived lipids are a mixed group that are not simple or compound lipids

General structure of a triglyceride



General structure of a triacylglycerol

Simple structure of triglyceride



Lipids cont’d

- Lipids that are liquids at room temperature of 22^{o}C are known as oils
- Those that are solids at room temp are known as fats.
- Fats and oils are esters of glycerol and fatty acids.
- Fatty acids differ in carbon number, unsaturation and structure. These factors affect the reactivity and functionality of fats and oils.

Lipids cont’d

- **Hydrogenation**: a reaction between hydrogen gas and unsaturated fatty acids in the presence of a catalyst (nickel, platinum or palladium
- If the process is controlled, different degrees of saturation can occur and fats with unique functional properties can be created. Products with improved shelf life,
- **Hydrolytic rancidity:** involves the cleavage of fatty acids from the glycerol either through chemical (deep frying) or enzymatic hydrolysis.

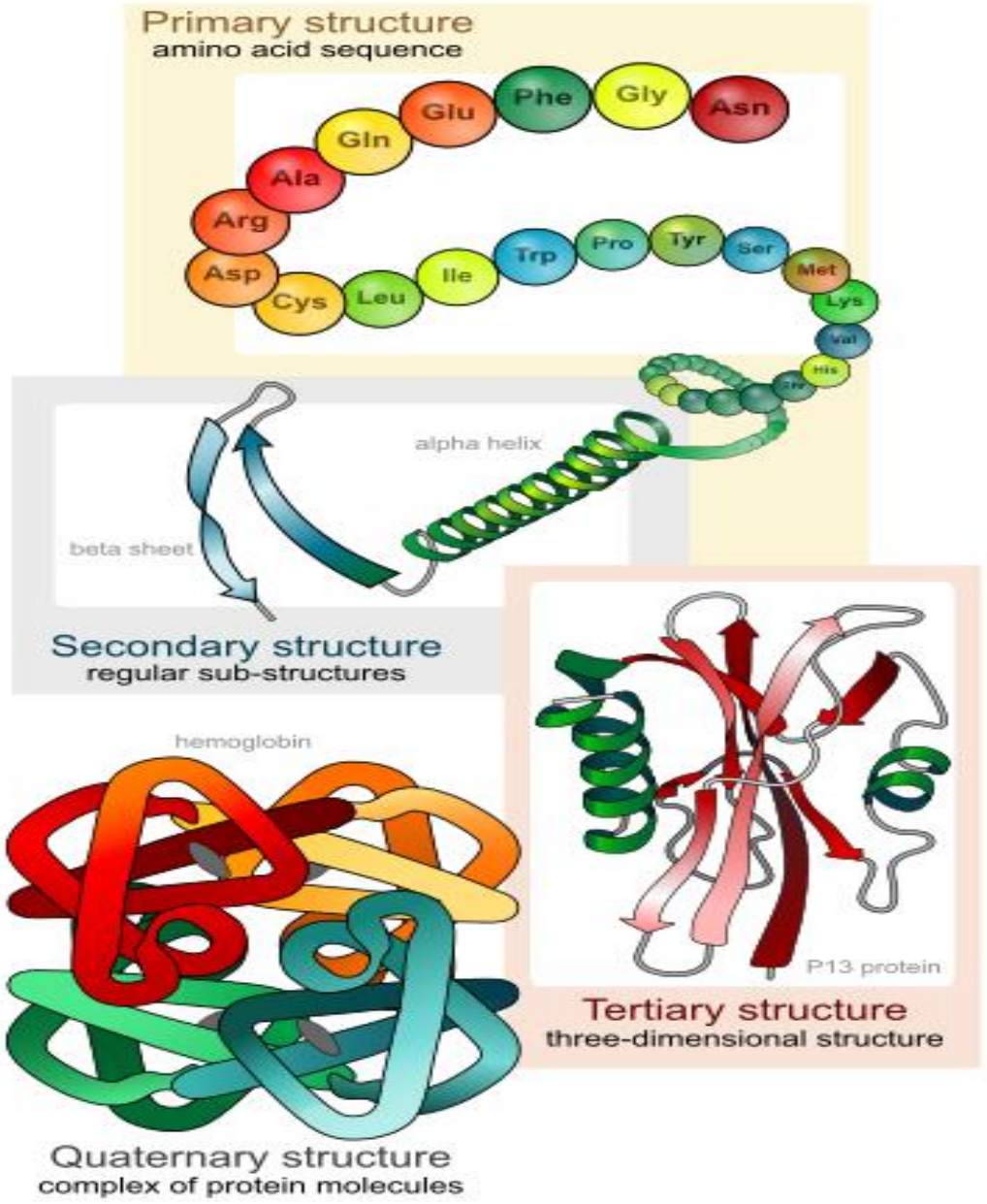
Lipids cont’d

- Hydrolytic rancidity is a concern because if short chain fatty acids are released they immediately impart on flavor and taste.
- **Oxidative rancidity** These are reactions between atmospheric oxygen and the lipid substrate present in a food.
- Lipids are highly reactive and most of their reactions are controlled by the food industry to yield highly desirable products, lack of control leads to the development of poor quality food.

PROTEINS

- Polymers of amino acids and are referred to polypeptides.
- 20 amino acids are commonly found in our foods, 8 are essential amino acids not synthesized by the body.
- Primary, secondary and tertiary structures
- Proteins undergo chemical modifications. These include hydrolysis, browning, alkaline degradation, changes in functionality and nutritive value, interaction with lipid and lipid oxidation products

The structure of protein



Proteins cont’d

- Proteins are likely the most multifunctional food ingredients and contribute greatly to the quality and sensory attributes of many formulated foods.
- The functional properties of protein include solubility, water holding ability, gelation, emulsification and foaming.

Proteins cont’d

- Proteins differ in size, shape, and amino acid composition and sequence. As a result, they differ in their functional behavior in food systems.
- Interactions of various reactive groups, such as thiol groups, and hydrophobic patches exposed on the surface of protein molecules lead to the formation of covalent as well as noncovalent intermolecular links, which result in protein aggregation and/or polymerization.
- Such molecular changes alter the functional properties of proteins, such as hydration, solubility, viscosity of solutions, film formation, gelling, and adsorption on the interface between aqueous and lipid phases

ADDITIVES

- Food additives are substances intentional added to food to achieve a technological function. The following are some of the uses:
- To maintain product consistency: emulsifiers, stabilizers, thickeners
- To improve or maintain nutritional value: Vitamin A & D, Ascorbic acid
- To maintain palatability and wholesomeness: preservatives, BHT, BHA
- To enhance flavor or impart desired color: non- nutritive sweeteners, MSG and food colors

Additive cont’d

- Food additives are more strictly regulated than any time in history. Food additives regulations require that evidence that each additive is safe at its intended level of use before it can be used in foods.
- Must function in a food system in accordance with its state function under specified conditions of use.
- Must not significantly dimish the nutritive value of a food
- A food additive must be detectable by a defined method of analysis

Interactions

- Interactions of food components with each other and with ions, proteins, and lipids affect various functional properties in food systems; these include water holding capacity, gelling, film-forming, viscosity, and other rheological behavior of fluids, inhibition of crystal growth, as well as formation and stability of foams and emulsions
- Polysaccharides also serve as entrapping or complexing agents for gases, liquids, and solids in foods.

Interactions cont’d

- The results of these interactions may be desirable, for example, browning of the crust of bread, in coffee roasting, or onion frying. In other cases, they may be detrimental for the food quality, for example, in stored condensed milk or dry vegetables.
- In many reactions flavor substances are produced, which may or may not be desirable, depending on the particular food. The nutritional value and safety of foods may decrease due to loss of valuable components or formation of some mutagenic and carcinogenic compounds.
- However, the gain in sensory quality is most often much higher than the small loss in biological value

Conclusion

- Chemistry is applied in product development as components are modified and rearranged to produce new products or to modify existing products using less expensive ingredients without altering the quality and safety of the product.
- Food chemistry is very essential to understanding food processing, quality assurance and sensory evaluation of food.
- Understanding and applying this vast chemical knowledge enables food scientists and technologist to design new food products that can conquer and stay in the demanding global market.

Quote

‘Knowledge is of two kinds.

We know the subject ourselves

or

We know where to find information on it’

Samuel Johnson

THANK YOU

ACKNOWLEDGEMENT / REFERENCES

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