Novel Technologies for Food Processing and Shelf Life Extension

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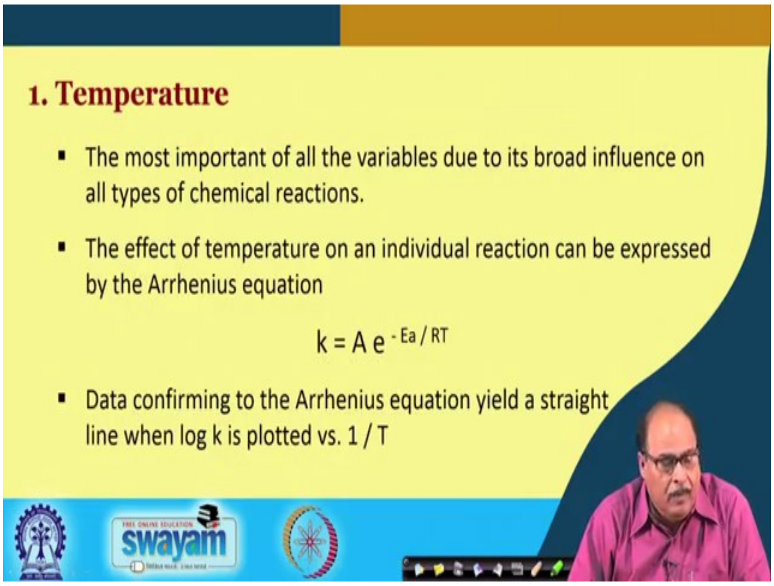
Lecture - 03

Factors Affecting Quality during Processing and Storage

In this lecture, different factors influencing the quality of food during processing and storage are discussed.

Some variables need to be controlled during processing and storage operations in order to get the desired quality in the product. The important variables include temperature, time, rate (dT/dt), pH of the ingredients, composition of the product, composition of the gaseous phase and water activity. These factors are important contributors to the overall quality of the product and therefore, the precise control of these parameters would be desirable.



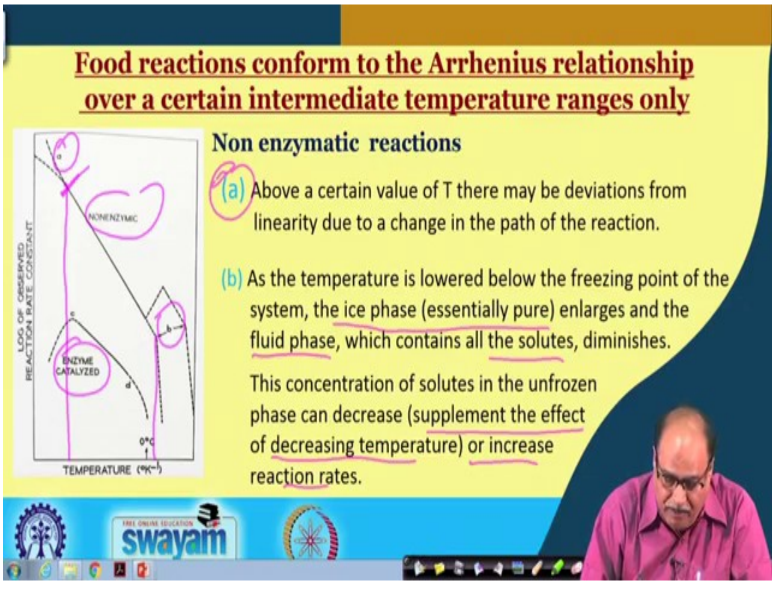
(1) Temperature

Temperature is important among all the variables because of its broad influence on almost all types of chemical and microbiological reactions which ultimately affect the quality of food. The effect of temperature on an individual reaction rate has been well explained by Arrhenius relationship which is expressed in the following equation.

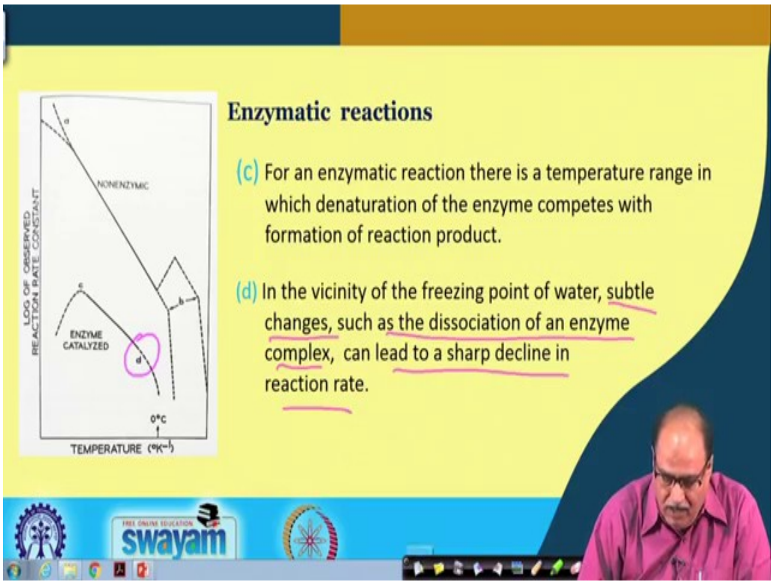
$$k = A\,e^{\frac{-E_a}{RT}}$$

Where, k is reaction rate, A is pre-exponential constant, E_a is activation energy, R is universal gas constant and T is absolute temperature.

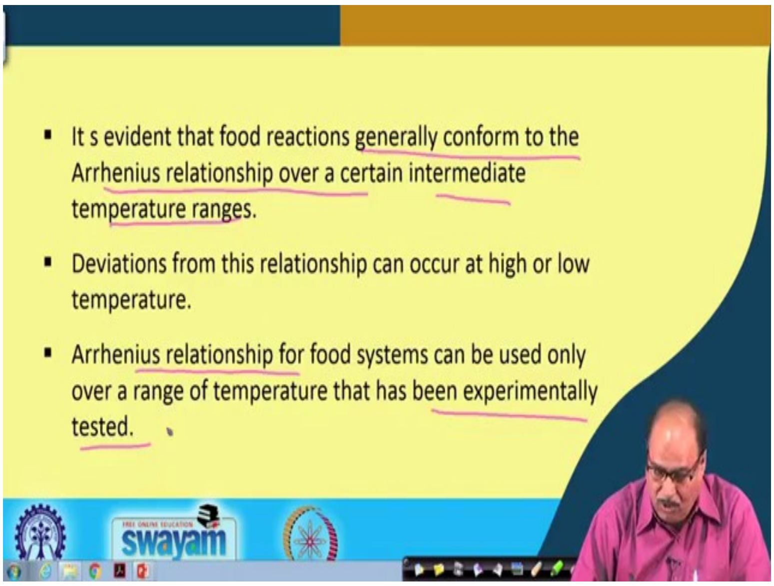
The data confirming the Arrhenius relationship generally yield a straight line if ln(k) is plotted against 1/T. This is well established as far as the chemical reaction kinetics is concerned.



However, in the food reactions, it has been seen that the components of the food usually confirm the Arrhenius relationship over a certain intermediate temperature range only. In the non-enzymatic reaction (see fig.), only the range (a-b) is following the linearity i.e. the Arrhenius relationship whereas the deviation from the linearity is taking place on both the sides i.e. on the higher temperature side and the lower temperature side. At the higher temperature side, above a certain value of the temperature depending upon the product characteristics or other variables present in the system in which the food is being processed, there might be deviations from the linearity because of the change in the path of the reaction. For example in the evaporation process, the rise in temperature causes evaporation of water and this increases the concentration of the solutes. Because of this change or increase in the solute concentration, the reaction path may change. When the temperature is lowered below the freezing point of the system, with the progress of time, the ice phase essentially enlarges and the fluid phase which contains all the solute diminishes. The concentration of the solutes in the unfrozen phase increases which causes a change in the properties of the material. This change in the properties can decrease or increase the reaction rate (point 'b') that depends upon nature and type of the solutes.

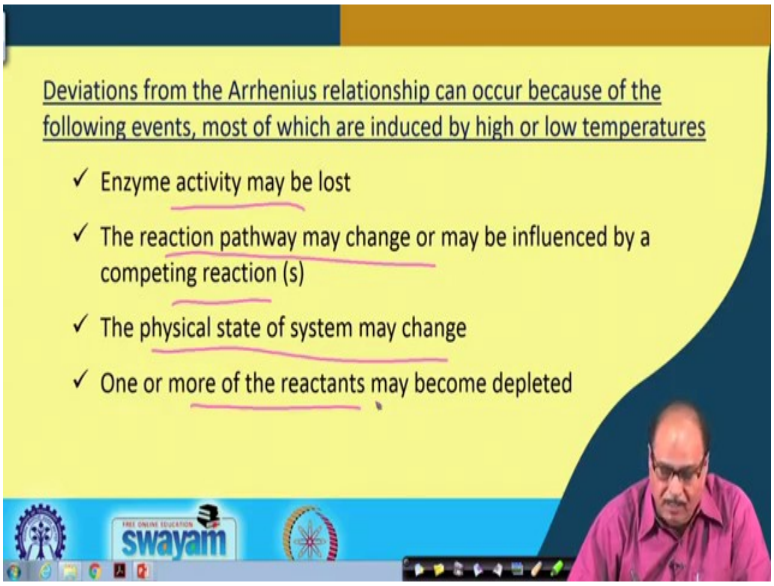


Enzymes are generally protein and temperature has a significant influence on it. In the enzymatic reaction, enzymes have got some acceptability over a certain temperature range during which it remains stable. Beyond that temperature range, the enzymatic reaction process is affected due to denaturation of proteins vis-a-vis inactivation of enzymes. In fact, the denaturation process competes with the product formation process and over the higher temperature side, denaturation process dominates, the reaction might even stop and that can be seen here in this figure at point 'c' wherein above a certain temperature, the reaction rate is decreased. In the vicinity of the freezing point of the water, subtle changes such as change in the dissociation of an enzyme complex or other such changes can lead to a sharp decline in the reaction rate.



So, these two examples are sufficient to explain that food reactions generally confirm to the Arrhenius relationship over a certain intermediate temperature range only and deviation can occur on either side. Therefore, the Arrhenius relationship should not be blindly applied to the food system.

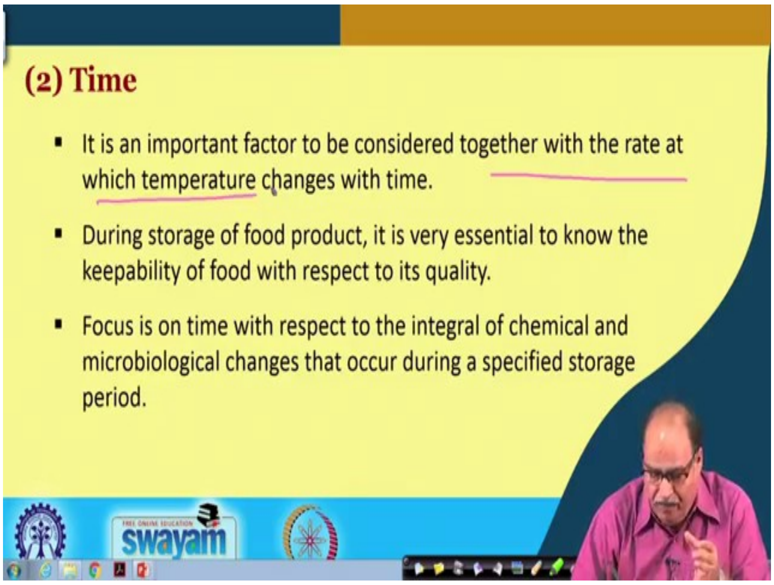
First depending upon the type of food using appropriate experiments, one should find out those temperature ranges which are following Arrhenius relationship. In modelling and other processes, the specific temperature range that has been experimentally tested should be used.



Overall, the deviations from the Arrhenius relationship in foods may be because of:

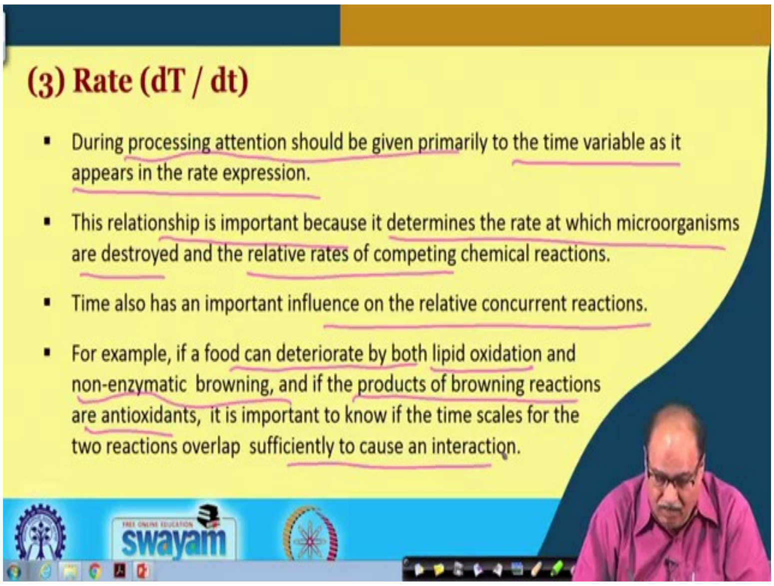
(i) The enzyme's activity might get lost depending upon the temperature and other factors.
(ii) The reaction pathway might get influenced by competing reactions.
(iii) The physical state of the system may change.
(iv) One or more of the reactants may become depleted.

These all factors together or individually influence the Arrhenius relationship.



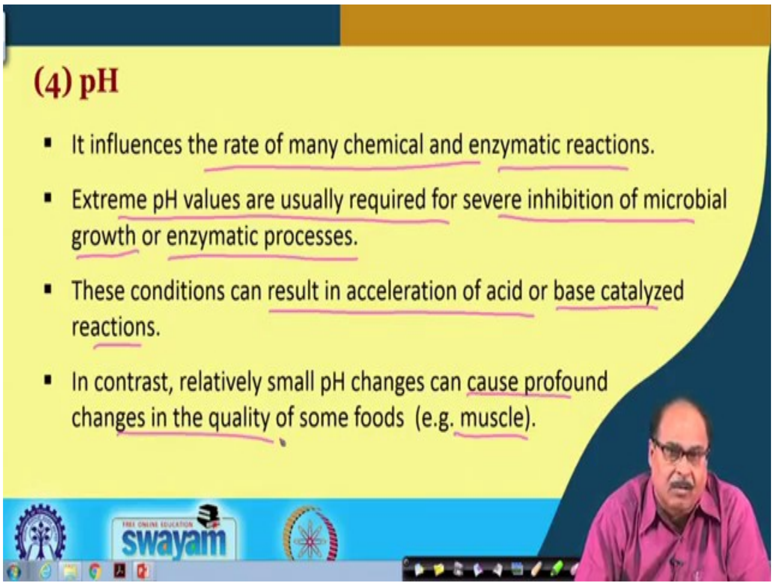
(2) Time

It is an important factor to be considered together with the rate at which the temperature changes with time. During storage of a food product, it is generally desired to know the keepability of the food. Keepability of the food means the quality that is focused on the time and risk with respect to the integral of chemical and microbiological changes that occur during a specified period of time.



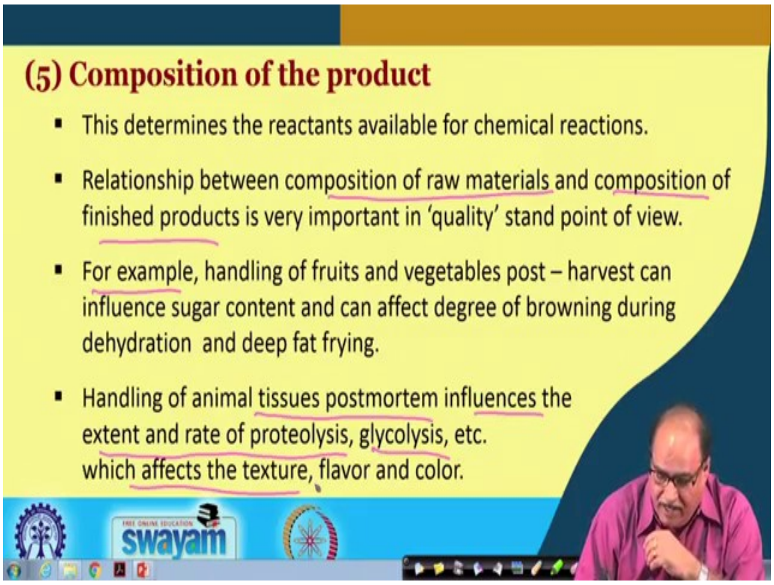
(3) Rate (dT/dt)

The rate becomes an important consideration during processing. The attention should be given to the time variable as it appears in the rate expression. The relationship (dT/dt) is important, because, it determines the rate at which the microorganisms are destroyed and the relative rates among the computing chemical reactions. For example, if a food can deteriorate both by lipid oxidation and non-enzymatic browning reaction, it is important to know if the time scales for the two reactions overlap sufficiently to cause a beneficial interaction.



(4) pH

The pH influences the rate of many chemical, microbioogical and enzymatic processes. In fact, most of the enzymes need optimum pH for their maximum activity. Extreme pH values are usually required for inhibition of microbial growth or enzymatic processes. The pH of the material may result in the acceleration of acid or base catalyzed reactions. Even small changes in the pH can cause a profound change in the quality of the food. The change of pH of muscle post-slaughter changes its textural and sensory characteristics. Even increase or decrease in the pH of the food might cause an increase or decrease in taste of the food. So, it becomes a very important variable one must consider during food processing.

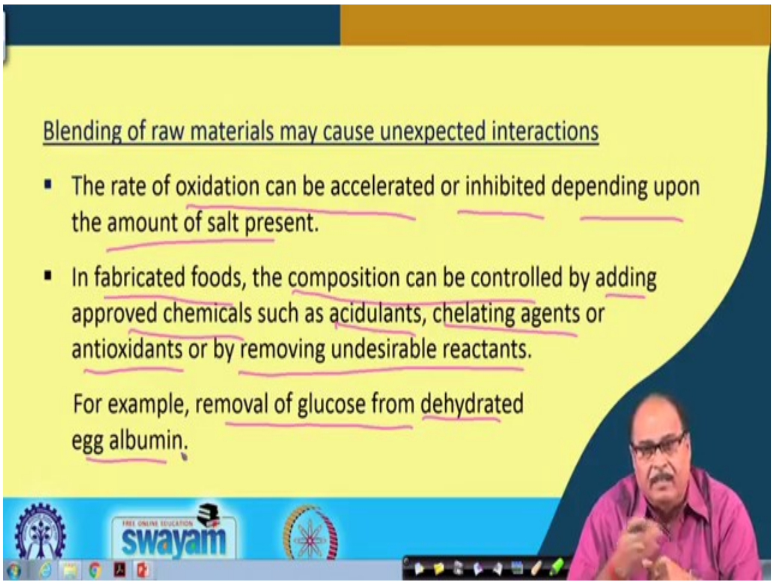


(5) Composition of the product

The other important variable which should be considered by processors who are handling food material in the industry are composition of the product, the raw material or ingredient, because the characteristic or composition of the ingredients and quality of the ingredients actually govern or control the quality of the end product.

The manner in which the fruits and vegetables are handled post-harvest can influence the sugar content and can affect the degree of browning during dehydration and deep fat frying, e.g. preparation of potato chips.

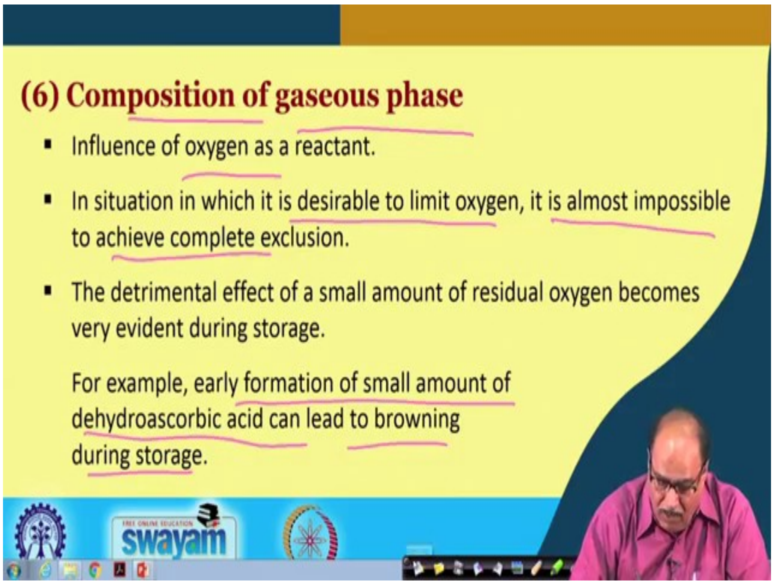
Similarly, in the case of muscle tissues, after slaughtering the manner in which these muscles are handled, influence the extent and rate of proteolysis, glycolysis, etc. which ultimately affects the texture, flavor, color and other attributes.



Even the blending of raw materials, if two or three or more ingredients are used, the type of ingredient, the proportion of ingredients, methods of blending/mixing, etc. may also influence the quality of food, e.g. the rate of oxidation reaction can be accelerated or can be decelerated, depending upon the amount of salt present in the mixture.

Similarly, in the case of a fabricated food, the composition of the product can be controlled by adding certain food grade approved chemicals such as acidulants, chelating agents, antioxidants or by removing undesirable reactants. Chelating agents can be added to bind the metal ions so that their reaction with the other component ceases.

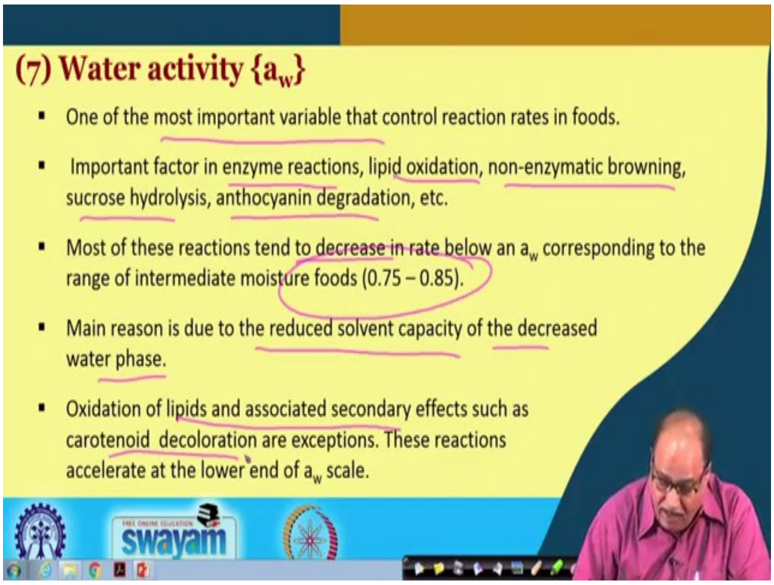
Antioxidants can be added to control the oxidative hydrolysis, oxidative rancidity and other reactions by removing the undesirable reactants from the system e.g., removal of glucose from dehydrated egg albumin improves the color and other characteristic of the powder, otherwise this glucose may react with the amino acids or amines that may result into the Maillard browning reaction and the egg powder ultimately becomes brown in color.



(6) Composition of gaseous phase

In addition to the composition of the ingredient, the composition of the environment in which the material is handled, processed and stored have important influences on the properties and characteristics of the product. For example, the presence or absence of oxygen may result in spoilage of food material due to microorganisms. There are many situations where oxidation processes can be avoided or limited. The instrumental methods or such other methods for the exclusion of oxygen can be employed. However, the complete exclusion of oxygen accelerates the anaerobic processes.

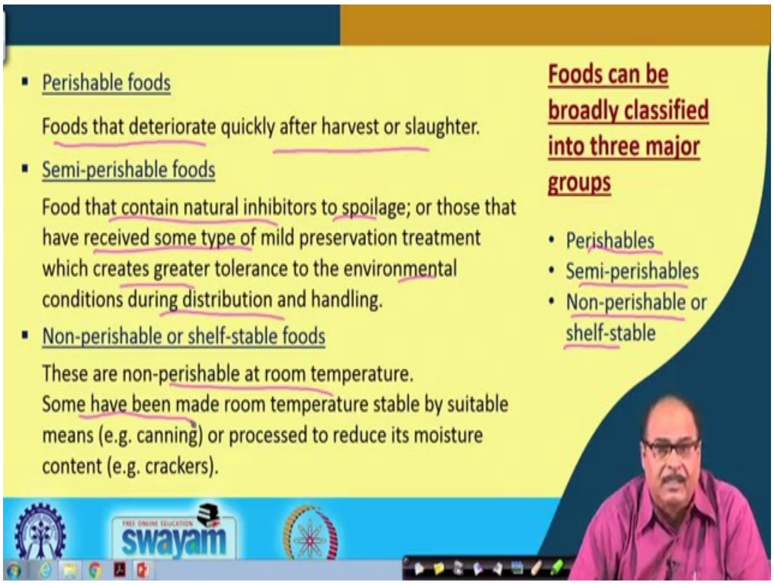
For example, in coffee, a small amount of oxygen might have a significant influence on the characteristics or quality of the product. During storage, even early formation of a small amount of dehydroascorbic acid by the oxidation of ascorbic acid can lead to the browning reaction. Therefore, oxygen becomes an important variable which should be properly checked and controlled.



(7) Water activity (a_w)

Water activity is one of the most important variables that control the reaction rate in food. It is not the water content, rather water activity that is important in food processing, handling and storage. Most of the enzymatic reactions, lipid oxidation, non-enzymatic browning reactions, sucrose hydrolysis, anthocyanin degradations, etc. are influenced by water activity. Many of these reactions tend to decrease at the lowest possible rate over the range of intermediate moisture food (0.75 to 0.85).

The reason for this is the reduced solvent capacity of the decreased water phase which reduces the rate of these reactions. However, lipid and associated secondary effects such as carotenoid degradation are exceptions because their rate is accelerated even at a low water activity. This is an overview of water activity which influences the characteristics or quality of the food material.



Types of foods

Depending upon the different constituents present particularly water and other components, the food is generally classified into three major groups:

(1) Perishable foods

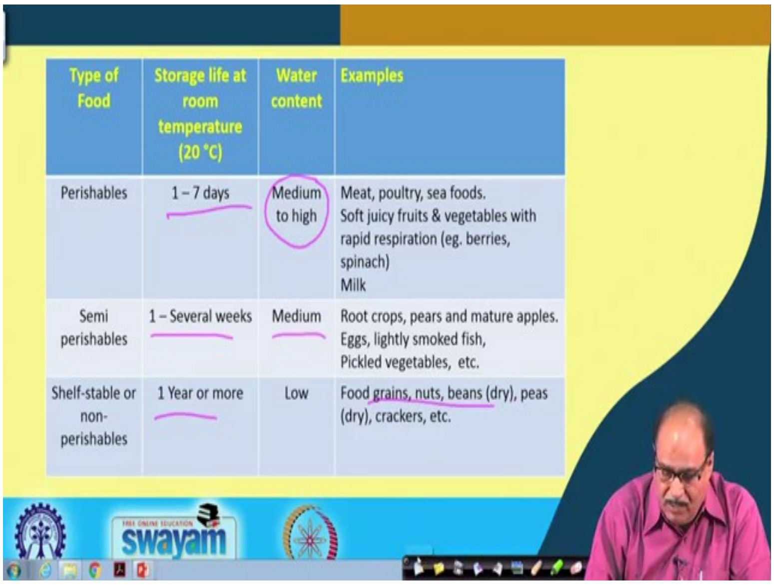
Perishable foods are those that deteriorate quickly after harvest or slaughter.

(2) Semi-perishable foods

Semi-perishable foods are those which contain natural inhibitors to spoilage or those that have been given some type of mild preservation treatment which creates greater tolerance to the environmental conditions during handling and distribution.

(3) Non-perishable or shelf stable foods

Shelf stable foods are those which are non-perishable at room temperature. Even some of these foods have been made room temperature stable by suitable processing means like canning or drying to reduce their moisture content to significantly lower values.

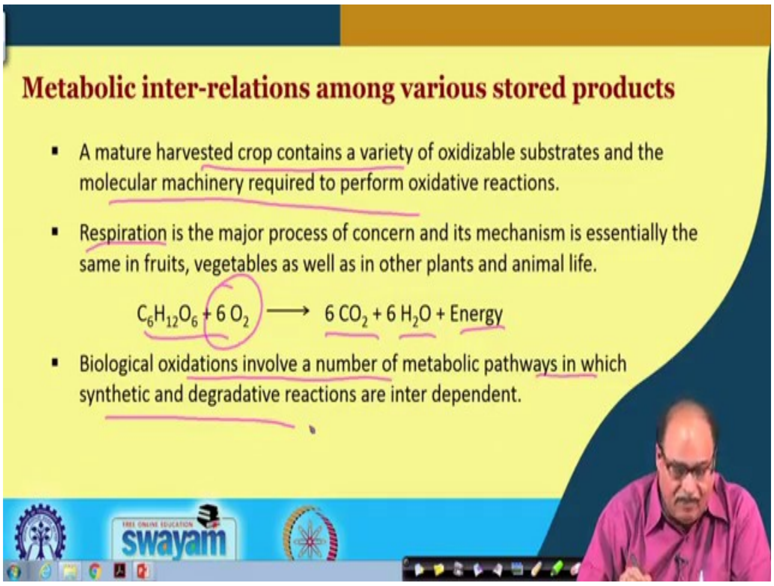


Type of Food	Storage life at room temperature (20 °C)	Water content	Examples
Perishables	1 – 7 days	Medium to high	Meat, poultry, sea foods. Soft juicy fruits & vegetables with rapid respiration (eg. berries, spinach) Milk
Semi perishables	1 – Several weeks	Medium	Root crops, pears and mature apples. Eggs, lightly smoked fish, Pickled vegetables, etc.
Shelf-stable or non-perishables	1 Year or more	Low	Food grains, nuts, beans (dry), peas (dry), crackers, etc.

In this table, it can be seen that, the perishable foods (e.g. poultry, sea-foods, milk, juicy vegetables, etc.) have medium to high moisture content and can be stored for 1 to 7 days at ambient condition. The semi-perishable foods (e.g. root crops, pears, eggs, pickled vegetables, etc.) contain medium water content which can be stored for 1 to several weeks depending on the storage environment. The shelf stable foods or non-perishable foods (e.g. food grains, nuts, beans, etc.) have longer stability at room temperature and can be stored for 1 year or more as they have low moisture content.

Shelf life

Another important aspect associated with the food quality and storage is the shelf life. The shelf life of food is a period between the processing and retail purchase and use of a food product. During this finite period of time, the product is in a state of satisfactory quality in terms of nutritional value, taste, appearance, flavor and use.



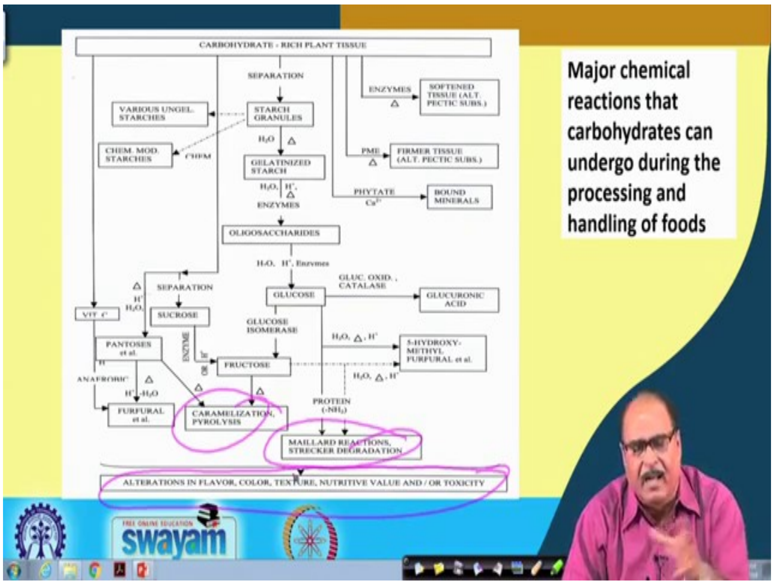
Metabolic inter-relations among various stored products

A mature harvested food crop/material contains a variety of oxidizable substrate and the molecular machinery which are required to perform oxidative reactions.

The respiration, wherein sugar is converted into carbon dioxide, water and energy under aerobic conditions, is the process of major concern. The mechanism of respiration reaction is essentially the same in fruit, vegetable or other plant and animal life.

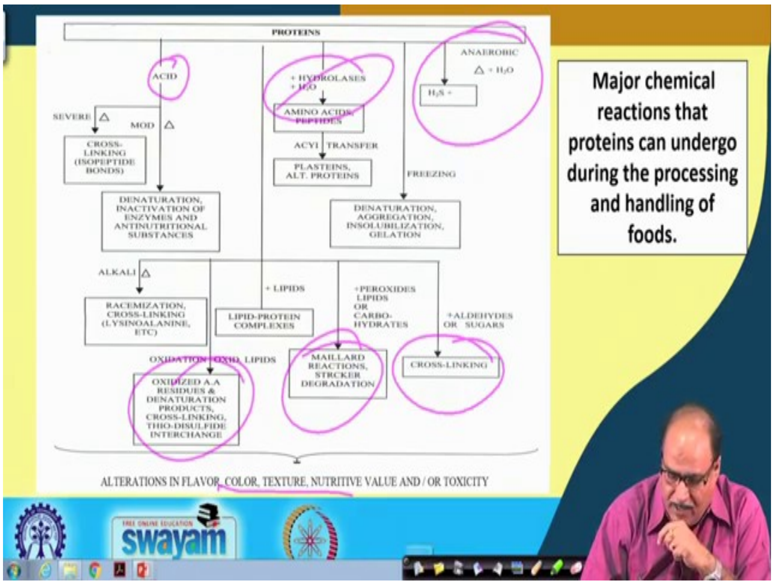
$$C_6H_{12}O_6 + 6\ O_2 \longrightarrow 6\ CO_2 + 6\ H_2O + \text{Energy}$$

The biological oxidations involve a number of metabolic pathways in which synthetic and degradative reactions are inter dependent. In most of the cases, the respiration and other oxidation reactions control the shelf life of the food material.

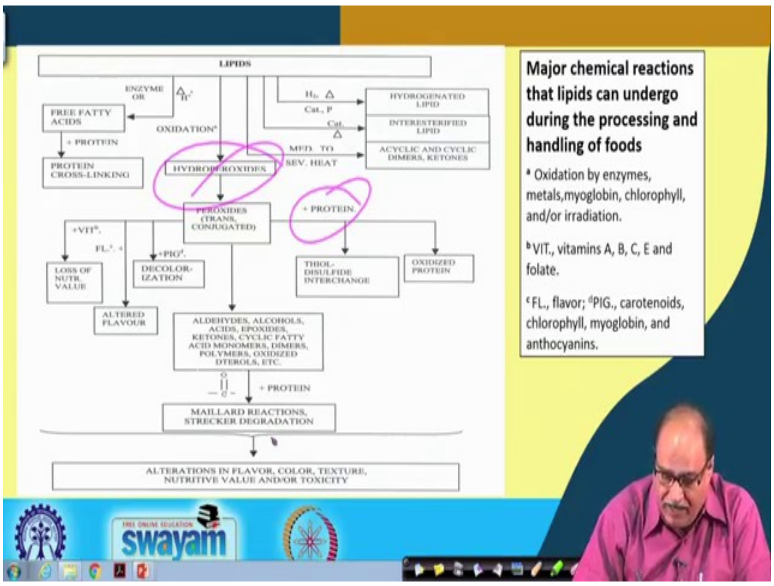


The major interactions and chemical changes among different components during processing and storage ultimately influence the quality of the food such as textural, sensory quality; color, flavor, nutritional value. These are the same set of the reaction which also might result in the development of certain toxic components.

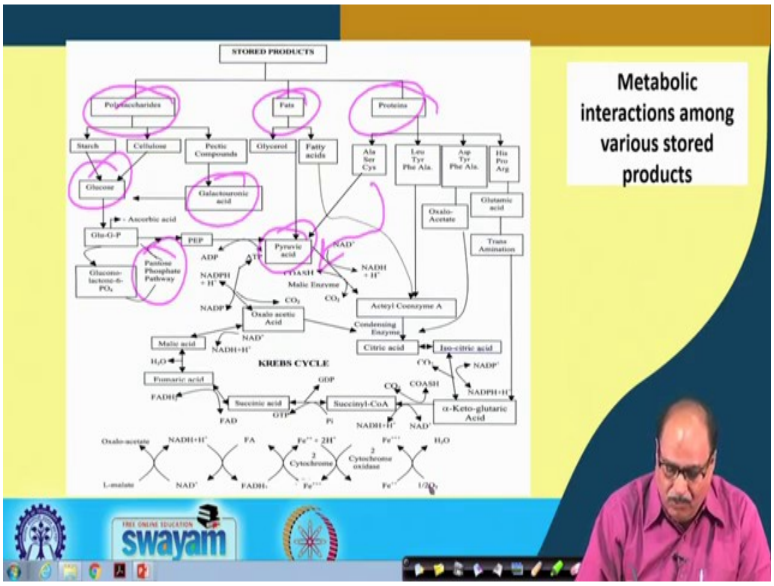
Carbohydrates include different polysaccharide, disaccharide, oligosaccharide, monosaccharide, etc. There may be different interactions among these constituents with proteins or lipids under different environmental and processing factors such as temperature, pressure, heat, acid, light, and various other factors. This ultimately results in decomposition, degradation or other changes in components and formation of various new carbonyl compounds like furfural, etc. There may be caramelization or pyrolysis, Maillard or Strecker degradation reactions which ultimately influence the quality of the product.



Similarly, in protein-rich food, the polypeptide can be broken down into di-, tri- and tetra-peptides, etc. Similar to carbohydrate, protein also may get in contact with acid or certain enzymes, water, even under anaerobic condition, etc. which induce different types of cross-linking, oxidation and Maillard reaction, etc. which result in the formation of various new compounds influencing the product characteristics. This graphical presentation gives an overview of the major chemical reactions which take place among the protein constituents and its interaction with other components of the food.



Similarly, the lipids may come across various factors like enzyme, temperature, heat, irradiation, air, etc. Lipids may undergo different reaction processes such as oxidation, interaction with the protein, formation of hydroperoxides, etc. These hydroperoxides may interact with protein and other components. Also, various carbonyl compounds may be formed which influence the quality of the food material.



This slide shows the interaction between major components of the food material during its handling or storage. The polysaccharide may be fragmented into pectic substances, celluloses, starches. There may be decomposition into smaller units like monosaccharide, glucose or galacturonic acid, etc. These components may enter into the glycolytic cycle or pentose phosphate pathways. Finally, it converts into pyruvic acid and at this stage, even the fat get decomposed to glycerol and fatty acids. This glycerol enters to the TCA (Tricarboxylic acid) cycle. Similarly, proteins under different conditions can be broken down into different amino acids. These amino acids like alanine, cysteine and serene interact with the pyruvic acid whereas, the histidine, proline, and arginine enter at a later stage in the TCA cycle and ultimately the series of complex reactions occur. Further in the oxidation reaction, energy is released from the system and other components are formed.

Therefore, it becomes an important consideration that during handling, processing and storage of the food, these factors must be meticulously and properly controlled to get the desired result in end products.