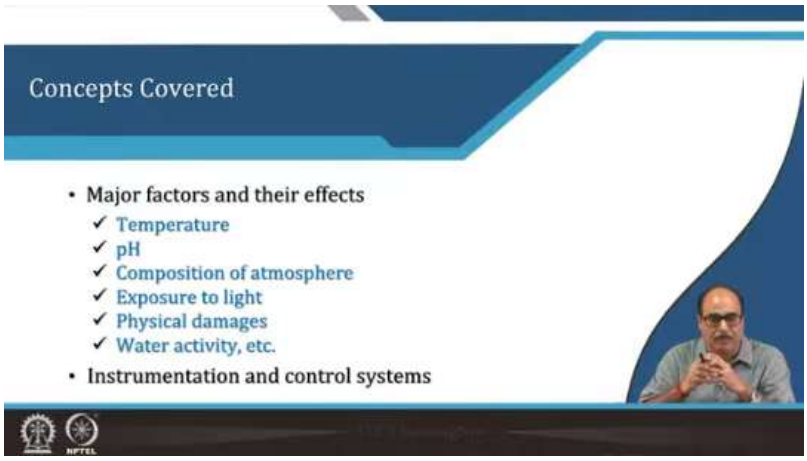
FOOD SCIENCE AND TECHNOLOGY

Lecture14

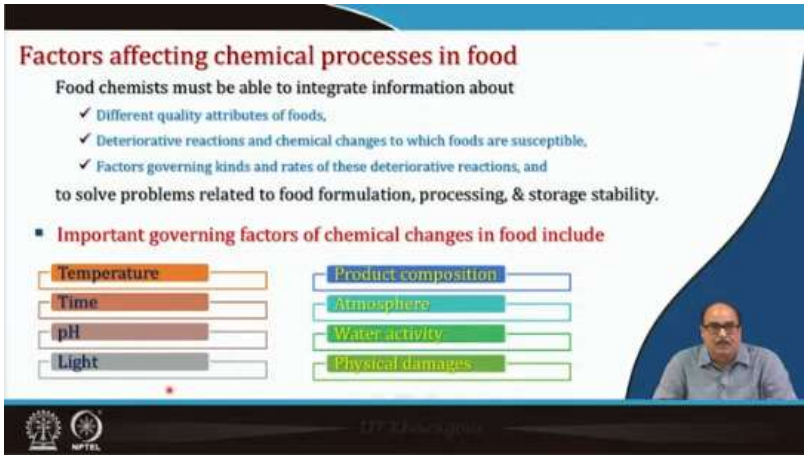
Lecture 14: Factors Affecting Chemical Changes in Foods

Hello everyone, Namaskar. Now, in this fourteenth lecture, we will study what are the various factors that affect the chemical processes or chemical changes in food.

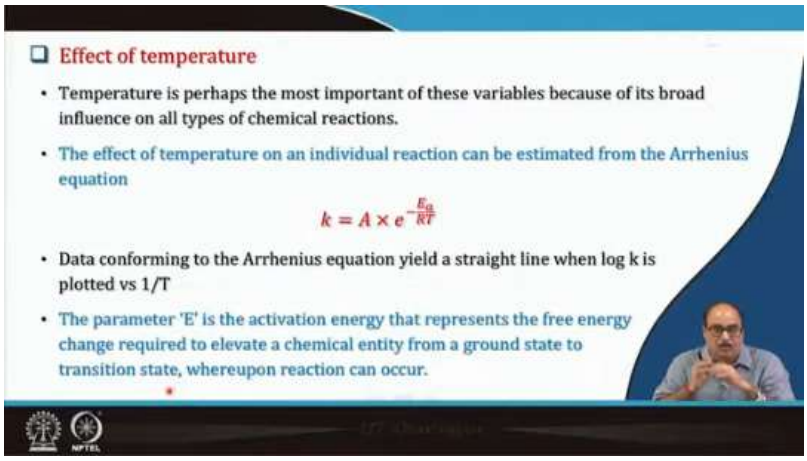


We will talk about the major factors and their effect, like temperature, pH, composition of the atmosphere, exposure to light, or even, there is a physical damage; then how it influences the quality or reactions and then water activity. So, these are the major factors which act upon the food during processing, storage, handling, etcetera. So, how they influence the chemical processes and this, of the changes, chemical changes in the food quality and safety. And also we will in the towards the end of the lecture we will talk

about what are the various instrumentation and control systems for measuring these factors, ok, for controlling these factors.

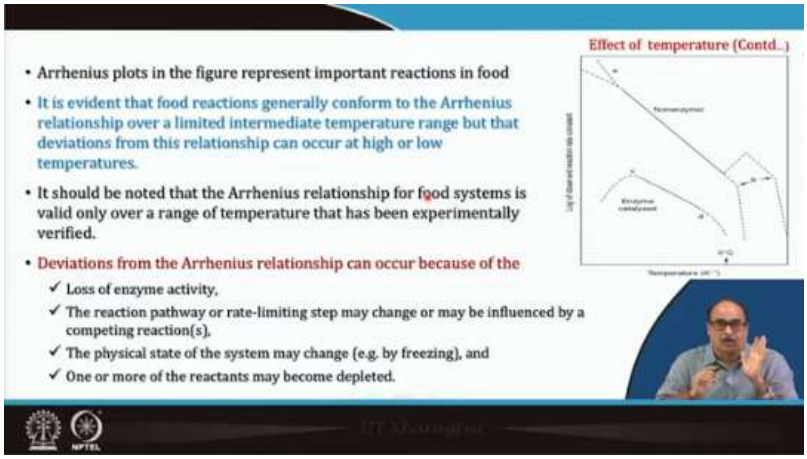


So, yes, factors affecting the chemical processes in food like the food chemist must be able to integrate the information about different quality attributes of the food, different deteriorative reactions and chemical changes in which the foods are susceptible, and the factors which govern that the kind and rates of these deteriorative reactions. And these are required basically to solve the problems related to food formulation, processing and also to have their proper storage stability, shelf life study. So, the important factors that govern the chemical changes in food include temperature, time, pH, light, the product composition or ingredient composition, atmosphere, surrounding atmosphere, that water activity, and also the physical damages. So, let us study one by one, the factor and their, its effect.



So, first thing is the temperature and you know temperature is perhaps the most important of all the variables because of its broad influence on all types of chemical reactions, even microbiological and chemical biochemical processes that are also they are influenced by the temperature. And in the earlier class also, in the earlier module, we briefly discussed this thing, that is effect of temperature on individual reaction. That is, the chemical reaction, it can be estimated from the Arrhenius equation.

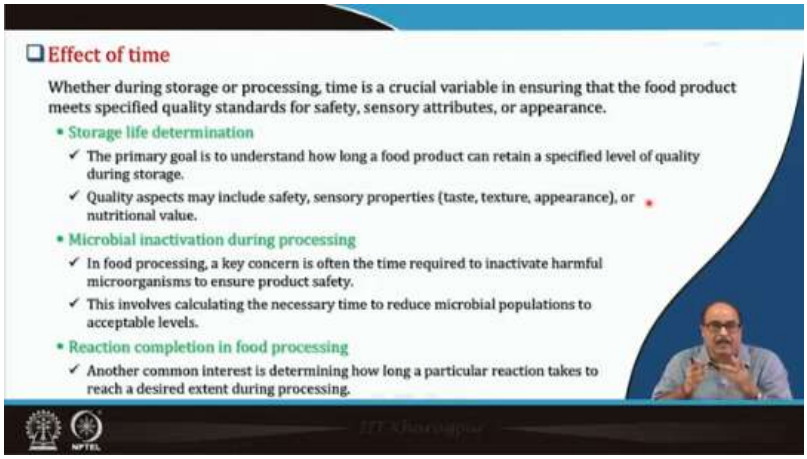
And the data which confirmed to the Arrhenius equation is a straight line when log of k is plotted versus 1/T. The parameter E, in this relationship, that is E_a energy of activation is the represents the free energy change required to elevate a chemical entity from a ground state to transition state wherever reactions occur or wherever reaction can occur.



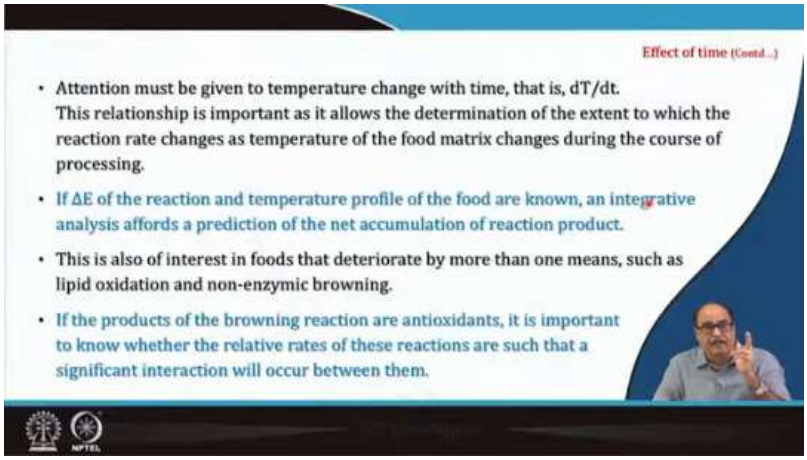
In the earlier also, we had discussed this, that is Arrhenius plots, here in the figure, represent the important enzymatic and non-enzymatic reactions, but it is evident from these processes, you can see here, that the reactions generally confirm to the Arrhenius relationship over a certain limited temperature range only and deviation may might occur from this relationship both at the higher or lower temperature side. And therefore, it should be noted that Arrhenius relationship should not be blindly applied in the port system; it should be applied over limited temperature range and that has been experimentally verified or experimentally decided.

So, the deviations from the relationship can occur because of the there might be lot of loss of the enzyme activity, the reaction pathway or the even the rate limit limiting steps may change or may be influenced by the competing reactions etcetera. The physical

states of the system may change, like in the case of what happens during freezing or concentration etcetera and one or more of the reactants may become depleted. So, because of these changes the changes in the linearity in the Arrhenius relationship there.



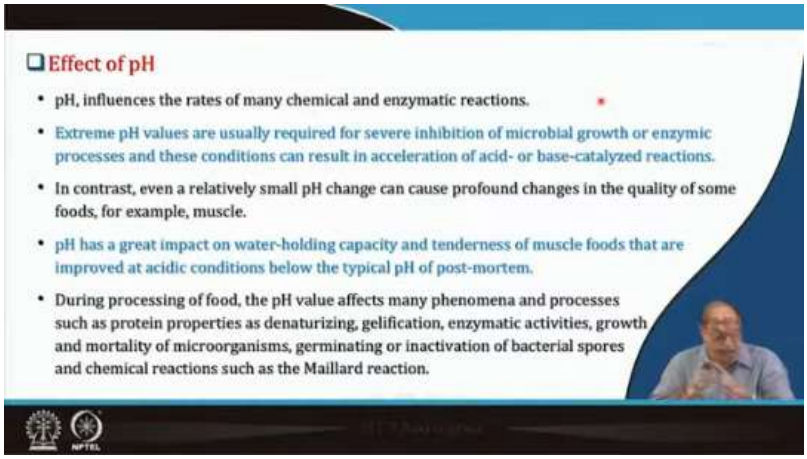
Then other effect variable is the time. Whether during storage or processing, time is a crucial variable in ensuring that the food product meets the specified quality standards or safety, sensory attributes, appearance, etcetera. Like, in the storage life determination, what basically we want; our primary goal is to understand how long food products can be retained, it can retain above a specified level of quality during storage. And the quality aspects may include safety, sensory properties, taste, texture, appearance or even the nutritional value. So, we see that, yes, on the basis of that, we decide the shelf life of a particular product. Even the microbial inactivation during processing, etcetera, we want to know that, yes, key concern is the often the what is the time, time required to inactivate harmful microorganism, to ensure product safety, or this involves calculating the necessary time to reduce microbial population to reduce to accepted levels. Then reaction completion in the food processing like determining how long a particular reaction takes to reach a desired extent during processing. So, this becomes the, time becomes the very important factors along with the temperature, the temperature.



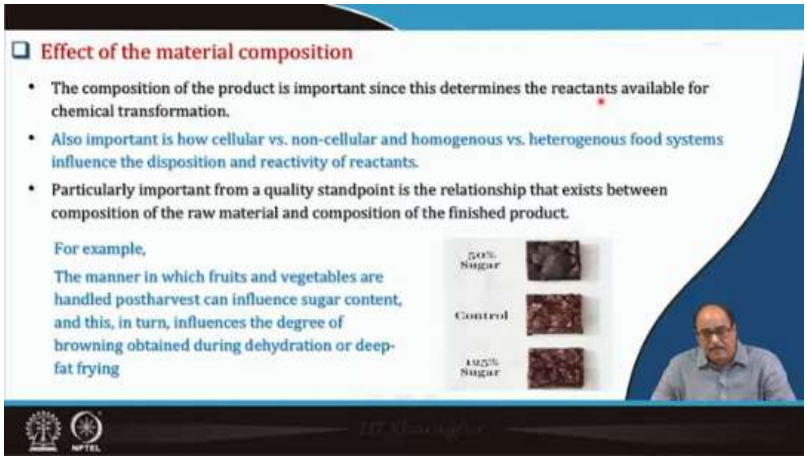
And then another very important thing is that, not only the time, but the time with which the temperature changes, the temperature the changes with the time like dT/dt, alright. And this relationship is very important because it allows the determination of the extent to which the reaction rate changes as the temperature of the food matrix changes during the course of processing. Temperature, alright. Then how the reaction rate is increasing or decreasing by these changes, increase or decrease in the temperature and then that it become, that is, here, so, time component should always be read along with the change in the time with the temperature, change with the temperature. If ΔE, that is the change of the certain reaction and temperature profile of the food are known and integrative of analysis can be undertaken to predict the net accumulation of reaction products as well as shelf life and all those things. This is also of interest in the food that deteriorate by more than one mean such as lipid oxidation, non enzymatic browning etcetera. Then also, that is, the time becomes. That is, if for example, a browning reactions, that is, these browning reactions, they may lead to melanoidins or melanins or many other unsaturated carbonyl compounds.

And it might so happen that some of these compounds which are result of the browning reactions, they might be having antioxidant properties. So, if it is so, then, it becomes very important to know whether the relative rates, relative rate of the browning reaction, development of antioxidant and lipid oxidation, etcetera, there is any concurrence or not. Because if there is a significant, whether there is, it may be that these antioxidants if there is a proper interaction, the significant interaction occurs, then this end product of the

browning reaction may help in stopping the lipid oxidation. So, that also, it becomes, the time and rate change of the reactions, that are, become very important.

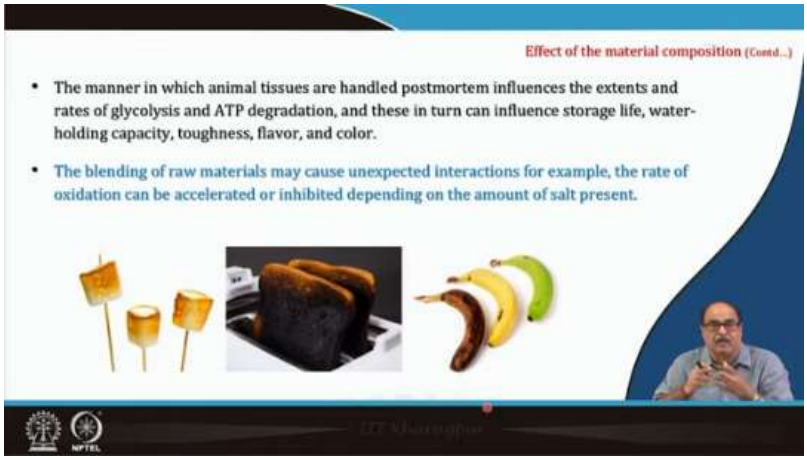


Then effect of pH: the pH influences again the rate of many chemical as well as biochemical enzymatic reactions. Extreme pH values are usually required for severe inhibition of the microbial growth or enzymatic processes and these conditions also result in the acceleration of acid or base catalyzed reactions. In context to even a relatively small pH change can cause a profound change in the quality of some product, particularly, for example, muscle in the muscle after slaughtering, that is, the animal is at there is a certain pH, physiological pH, and then this pH changes comes to the ultimate pH and this change in the pH post slaughter brings about changes in the quality of the muscle, etcetera. pH has a great impact on water holding capacity and tenderness of the muscle foods, and that are improved at acidic conditions below the typical pH of the postmortem. And during processing of foods, the pH value affects many phenomena and processes such as protein properties, denaturizing, gelification, enzymatic activities, growth and mortality of microorganism, germination or inactivation of bacterial spores, chemical reactions like Maillard reactions and many other reactions, they are all influenced by the pH.

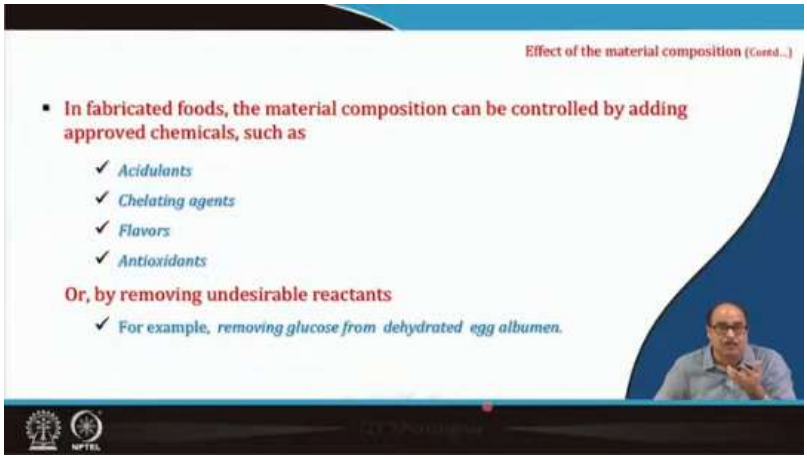


Then material composition, effect of the material composition, like composition of the ingredient that is the and it is important since this because it determines the reactants available for the chemical transformations. It is also important that how cellular as well as versus non cellular and homogeneous versus heterogeneous food systems influence the disposition and the reactivity of reactants. Disposition and reactivity of the reactants: particularly important from a quality standpoint is relationship that exists between the composition of the raw material and composition of the finished product.

Because if the raw material composition and quality is not very good, we cannot expect that is a miracle to happen or you can the product, end product characteristics is to great extent depends upon the initial material characteristics. So, like the manner in which fruits and vegetables are handled post harvest can influence the sugar content. And, if the fruits, vegetable like potato etcetera such other, they are having more sugar. So, obviously, it will influence the degree of browning often during dehydration or deep fried frying etcetera. And, then the products fried are made, that chips, etcetera, for example, they may develop more brown color during drying, frying, and that may not be liked by the consumers. So, that depends that is what how the raw material ingredient's quality.

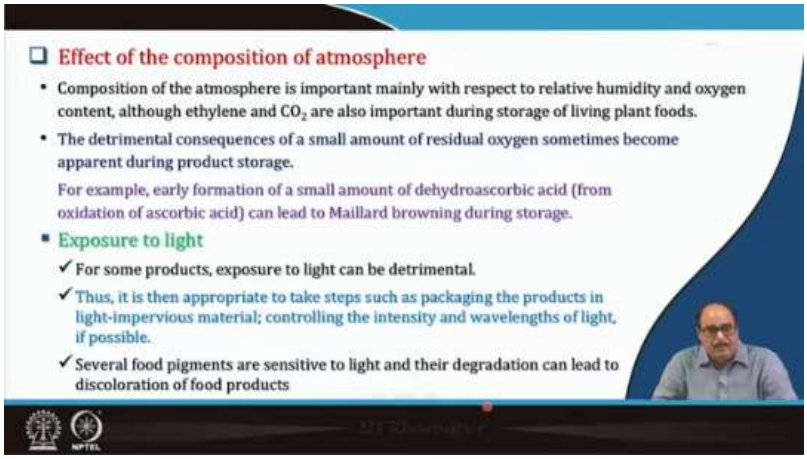


The manner in which that animal tissues are handled post mortem influences the extent and rate of glycolysis and ATP degradation and these in turn can influence storage life, water holding capacity, toughness, flavour and the colour of the products. Even the blending of raw materials also may cause unexpected interactions. For example, the rate at which the oxidation can be accelerated or the rate of the oxidation can be inhibited depending upon the amount of salt present in it.



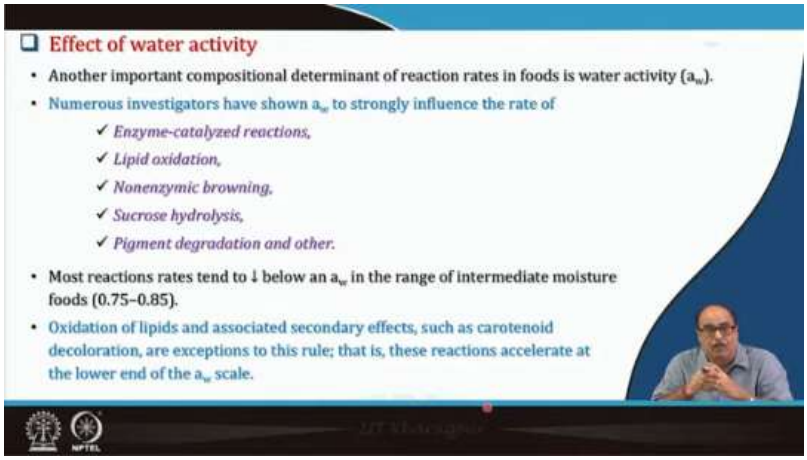
So, again the raw material. Many a times, even, that, in the fabricated foods, in the manufactured food, engineered food, the material composition can be controlled by adding approved permitted chemicals or additives etcetera like acidulants, chelating agents, flavors, flavor enhancers, antioxidants, surfactant, many surfactant active agents etcetera emulsifiers and all. They are added, many a times, into the food system to bring desirable interactions and therefore, to get the desirable characteristics in the product. Similarly, on the other hand, that, we can also get the desirable properties by removing

the undesirable reactants, like for example, removing glucose from the egg albumen, before its dehydration so that you can get particularly very white colored dehydrated egg albumen or egg powder.

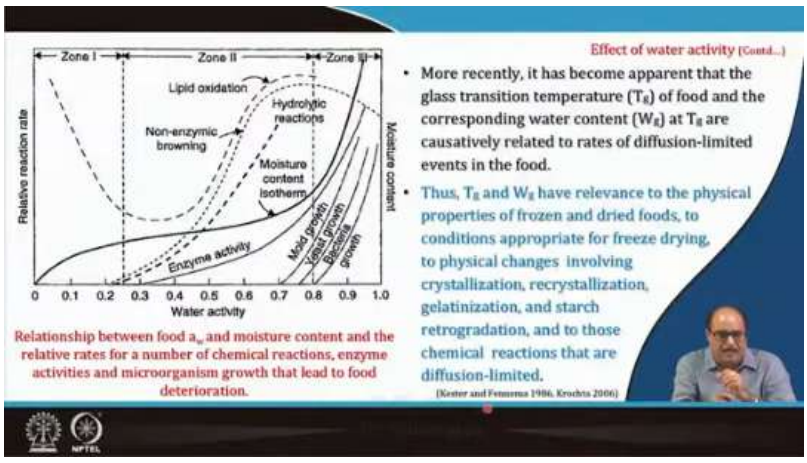


Then effect of the composition of the atmosphere, that is, whether it is a aerobic environment, anaerobic environment, more CO2 is there and else more nitrogen environment etcetera is there. So, that is all composition of the environment or atmosphere is very important in mainly with respect to the relative humidity, oxygen content, although ethylene and CO2 also are important during storage of the living plant foods. So, the detrimental consequences of a small amount of residual oxygen sometimes become apparent during product storage. For example, early formation of a small amounts of dehydroascorbic acid from the oxidation of ascorbic acid can lead to Maillard reaction, Maillard browning reaction during storage. Even in some of the high value products, a small amount of oxygen, residual oxygen may change, may result into the quality changing in the products like coffee, etcetera.

Also the exposure to light: for some products, exposure to light can be detrimental. It is that then appropriate to take steps such as packaging the product in light impervious material, controlling the intensity and wavelength of the light if possible or even various other way one should see that is those reactions those products which has, which can be changed, which are sensitive to light. So, this care, appropriate care should be taken. Several food pigments are sensitive to light and their degradation can lead to discoloration of the food product or other things.



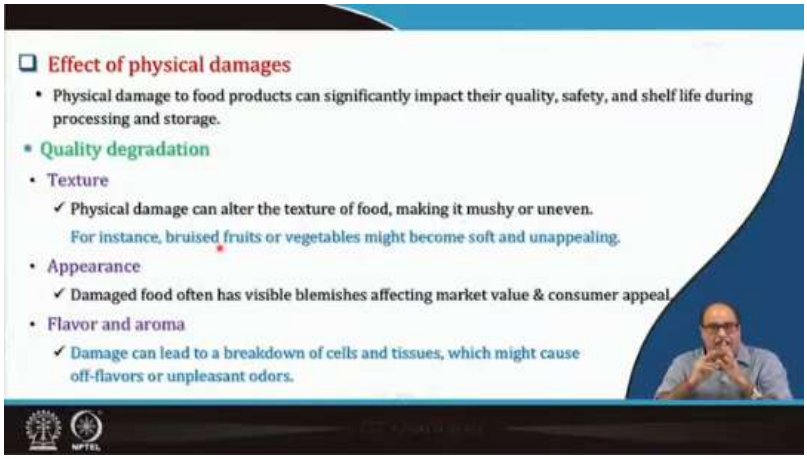
Then effect of water activity, very important factor, important compositional determinant of reaction rates in food is water activity. Numerous investigators have shown that water activity strongly influences the rate of many reactions, like enzyme catalyzed reactions, lipid oxidation reaction, that non-enzymatic browning, sucrose hydrolysis, pigment degradation and so on. So, almost all most of the reactions they are influenced by the water activity. Most reaction rates tend to decrease or slow down below an water activity in the range of intermediate moisture foods, that is, within aw ranges of 0.75 to 0.85. However, oxidation of lipids and associated secondary effects such as carotenoid decoloration, are exception to this rule and this reactions accelerate at a very very low water activity ranges that is the even less than 0.2 or 0.1. This is the exception to this rule otherwise that by reducing the water activity reactions rate decreases.



As you can see here, that is the, more recently it has become apparent that the glass transition temperature if you look at the Tg of food and the corresponding water content

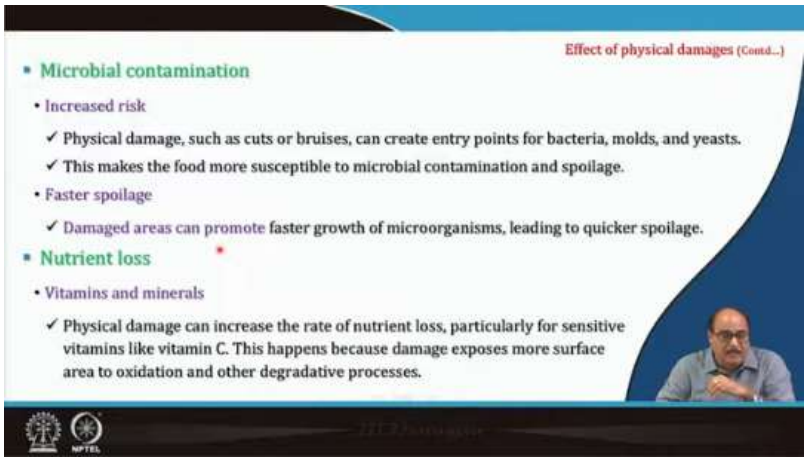
Wg, they are closely related to the rates of diffusion limited events in the food. Thus if the Tg and Wg have relevance to the physical properties of frozen and dried food to the conditions appropriate for freeze drying to physical changes involving crystallization, recrystallization, gelatinization, starch retrogradation and those chemical reactions that are diffusion limited. Here, in this figure, you can see, it is a relationship between water activity and moisture content and the relative rates of a number of chemical reaction whether it is non-enzymatic browning, lipid oxidation, hydrolytic reactions, moisture sorption isotherm, enzyme activity, mold growth, yeast growth, bacterial growth, and so many. All these reactions, etcetera, you can say it is shown, and most of the reactions generally at the boundary of the zone 1 and zone 2 they say here, may be somewhere at around 0.25 or so at water activity, that is, the at this range, the reaction rate becomes minimum except for that the lipid oxidation reactions.

Lipid oxidation, you can see, where you at lower water, the lipid oxidation rate is more and then again, of course, it becomes minimum at this range and then the reaction rate becomes, again increases, and it reaches maximum at the boundary of the second and third zone and then further it can be decreasing or it may go further. So, these are the reaction that is most of the thing that is may require 0.25 0.32 or either 0.75 to 0.85 in this row. So, you bring down the, as I told you, the water activity below 0.8 or 0.7, most of the reactions will be decrease and then it is it decreases further.

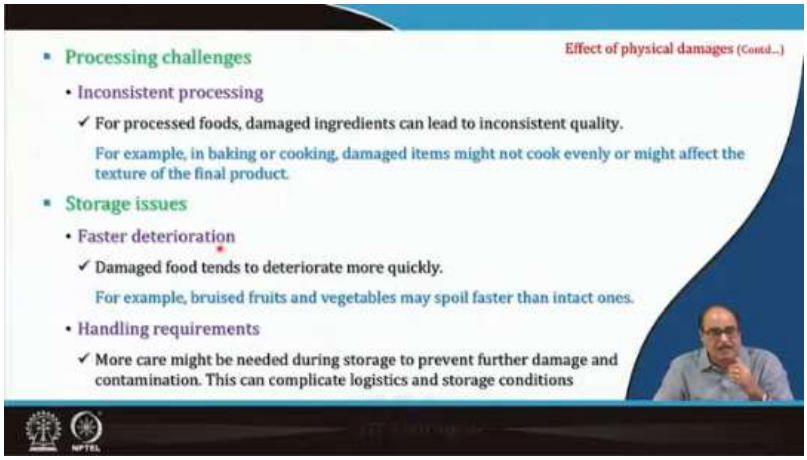


Then, effect of physical damages on the quality: physical damage of the product can significantly impact their quality, safety, shelf life during processing and storing. The

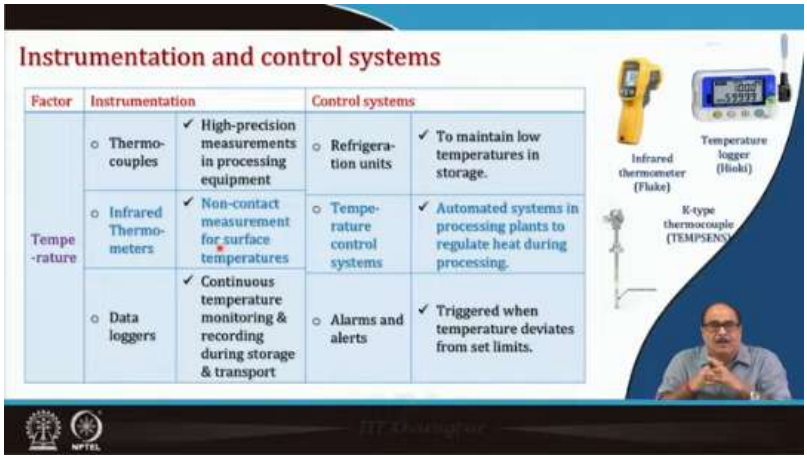
quality degradation, there will be effect on texture, that is, the physical damage can alter the texture of food making it mushy or uneven. For example, bruised fruits and vegetables might become soft and unappealing, then damaged food has sometime visible blemish effect; market value and the consumer appeal is reduced and its appearance gets affected. And then also damage can lead to breakdown of cells and tissues which might cause off-flavor development or development of unpleasant odors, etcetera.



Then, microbiological contamination also, if there is, there will be increased risk; physical damage like cut, bruises etcetera can create entry points for bacteria, molds and yeast and this makes the food more susceptible to microbial contamination and spoilage; even the damaged area can promote faster growth of microorganism leading to quicker spoilage. Or even also, it can act as a, physical damage can increase the rate of nutrient losses also, particularly for sensitive vitamins like vitamin C etcetera because it happens because If there is a damage on the tissue or physical damage, then it exposes more surface area to oxidation, oxygen becomes easily accessible in the products and their oxidation and other degradative reactions, their rate increases.



Similarly, the there are certain processing challenge like inconsistent processing for processed foods, damaged ingredients can lead to inconsistent quality like in the baking or in cooking processes, damaged items might not cook evenly or might not might affect the texture of the final product. Then, also, there might be storage issues like faster deterioration. Damaged food tends to deteriorate more quickly, like bruised fruits and vegetables may spoil faster than the intact ones. Similarly, handling requirement like more care might be needed during the storage to prevent further damage and contamination and this can complicate logistics and storage conditions.

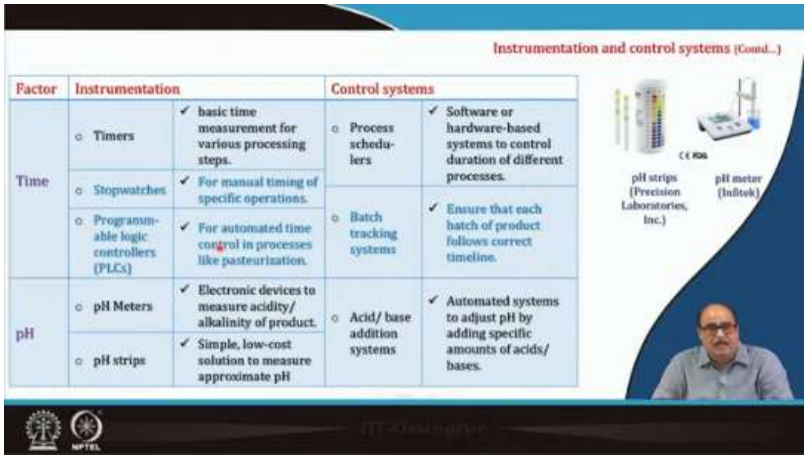


Then, we talk about instruments and control systems, that is, what are the various instruments that are, which can be used to control these, many a time, during processing, handling or storage. We need to maintain a particular condition, that is, like, for example, you want your process consistently at 70 °C temperature or 80 °C or 100 °C. So, there should be something. Number one, that is: how you measure that is whether really the 70

or 80 °C temperature has been arrived or not. So, first some heating system and then some indicator system should be there. So, to know that, yes, now desired temperature has reached. Then how to control this. That is, so that now there is no further increase in temperature So, there are this, first instrumentation instrument to measure these variable, and to control this.

So, let us talk about first: temperature, That is, even there are various instrument to measure the temperature like thermocouples, infrared thermometers, data loggers etcetera. These thermocouples, they are required, they give high precision measurements in processing equipment etcetera. But there are normally they like refrigeration units in that to maintain how low temperature in storage conditions and all those things they can be used to control their low temperature etcetera regulate the temperature in the refrigerator, refrigeration units, and all those things.

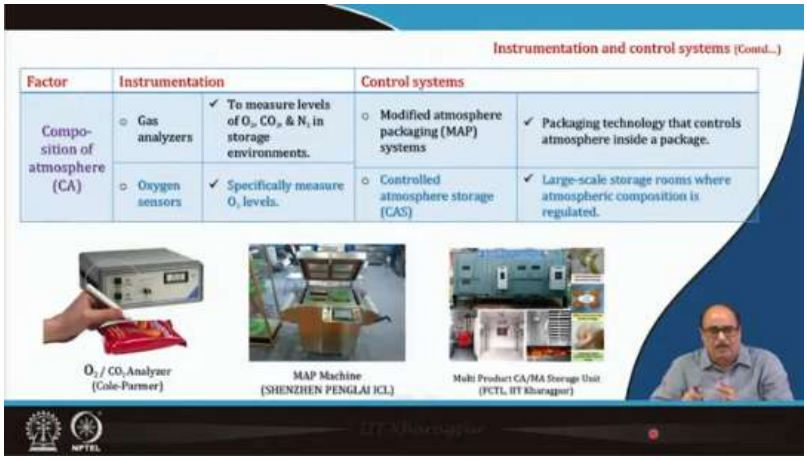
Similarly, infrared thermometers, like, they are non contact measurement for; they can be used for non contact measurement for surface temperatures. And of course, there are temperature control system can be used. And, this is the, in the automated system in processing plants to regulate heat process, heat during processing, and so on. Then data loggers: they are continuous temperature monitoring and recording during the storage and transport. They can, they have some alarms and alerts, etcetera for the set, which can use the temperature trigger when temperature deviates from the set value. So, these alarms and alerts etcetera are, that is the, in the data loggers and which can tell you, that is, if the temperature is either maintained or not properly.



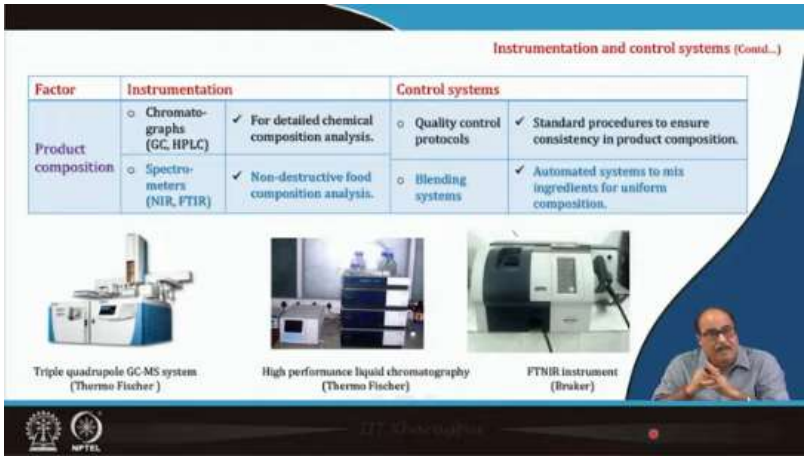
And similarly the time: this time means there might be where the different timers, stopwatches, programmable logic controllers like PLC etcetera ok. So, these timers, the basic time measurement for various processing steps, like process schedulers, etcetera in the control system, and then software or hardware based systems are there to control duration of different processes. Even stopwatches for manual timing of the specific operations or programmable logic controller that is popularly known PLC. PLC's for automated time control in process like pasteurization or other sterilization etcetera ok.

And so, the control systems are the batch tracking systems, which ensure that each batch of the product follows correct timelines etcetera. Then for the pH, there will be either pH meters, or pH strips sometimes can be used to indicate the pH. So, these pH meters are electronic devices to measure acidity or alkalinity of the product, or the pH strips are simple low cost solution to measure approximate pH. These are, sometime they give approximate pH; they change the there are a strips which change the color with the pH.

So, control systems may be acid or base addition systems and automated systems to adjust pH by adding a specific amount of acids and bases are there in. Sometimes, in the suppose, you are in a continuous monitoring, continuous processing, etcetera, and like in many fermented reactions etcetera, you maintain that proper acidic acid proper pH if you want to maintain a proper alkaline condition particularly. So, there, in the system these are provided with the regulated, that is the tanks containing appropriate acid or appropriate alkali and as and when required, they are regulated, their regulation, addition etcetera. So, that the pH, whenever they are, you have set the pH, alright, at a particular, there are fermenters, you have the set the pH suppose you have want the pH to maintain at 4.5. And the whenever there is a pH deviation it will go up or it will go down, accordingly there are acid and alkali valves, they are automatically regulated, they will open and they will drop into the fermenter and the appropriate pH is maintained. Once the appropriate pH is maintained they will again stop.



And then, this composition of the atmosphere, like gas analyzers or oxygen sensors, etcetera. There are various analyzers with systems which can analyze or measure the levels of oxygen, carbon dioxide or nitrogen in the storage environment. or even there were various sensors, especially measure O_2 labels or even carbon dioxide sensors, nitrogen sensors various sensors are there which can sense the environment and tell that whether it is aerobic environment, anaerobic environment or nitrogen environment, whatever they are. And these can be properly, there are control system which are used many a times in the modified atmospheric packaging etcetera where you want that is within the package there should be a particular amount of oxygen, O_2, CO_2 environment or in the controlled atmosphere storage, various sensors, various controlling devices, temperature controlling devices, O_2 controlling devices or nitrogen containing devices, carbon dioxide can be by cylinder. So, you can both for the packaging technology, like that control the atmosphere inside the package, modified atmosphere packaging or large scale storage rooms where atmospheric composition is regulated in the like that in the control atmosphere storage. There are various systems instrumentation and systems that are available.



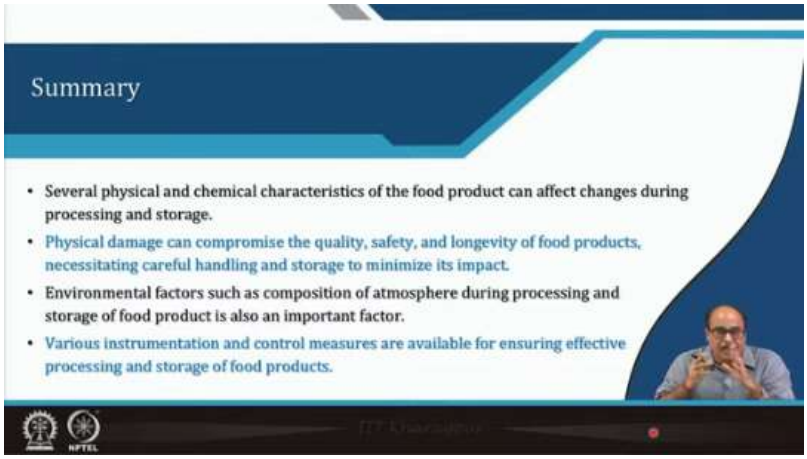
Similarly, for analyzing the composition of the product, like composition of the product, like there are systems like instruments like gas chromatograph like GC, high pressure liquid high performance liquid chromatography HPLC and such other equipment. And, they can be used for detailed compositional analysis or there are various quality control protocols which are used as control systems, and then standard procedure to ensure that there is a consistency in the product composition or not. There various spectrophotometers are many other such equipment like NIR spectrophotometer, FTIR, normal spectrophotometer etcetera which are used for non-destructive food composition analysis; like blending systems and there are automated system to mix ingredients for uniform composition and so on. So, all these various systems can be used for analysis and measure.

Then for even instruments for exposure to light, there are light meters or UV sensors can be used. Light meters which measure the intensity and spectrum of light exposure ok.

And the control system may be light filtering packaging or the or packaging that blocks or reduces the light exposure. Then in the case of UV sensor, there are, this is specifically measure ultraviolet light exposure.

They are controlled lighting systems are in storage areas to minimize unnecessary light exposure. Physical damages like impact sensors are there or visual inspection systems like impact sensors, they directly detect the physical shocks or impacts during handling etcetera. Like in the case of protective packaging, the use of cushioning material to prevent damage and all those things. So, the these might be act as some sort of control system controlling the physical damage.

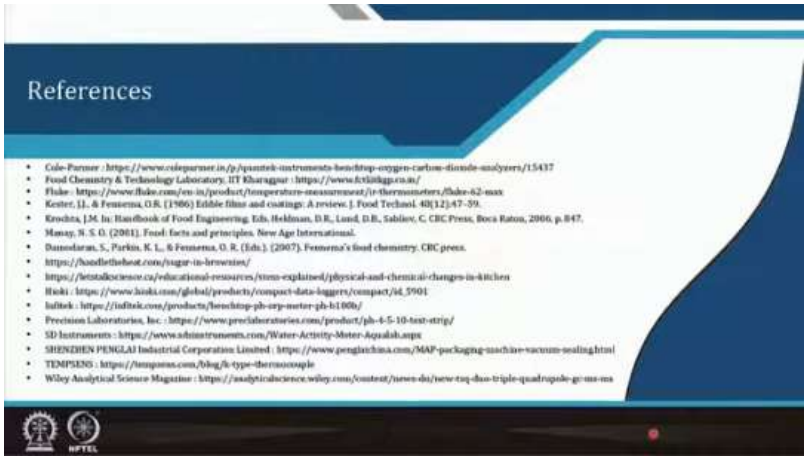
Similarly, visual inspection systems like automated systems which have camera, etcetera, and these camera detects the physical damage, and the gentle handling systems are conveyors and robotic arms, etcetera, which are designed to minimize impact. Then, water activity: in the water activity there are various water activity measures meters instruments that measure the water activity in the food like it can be done either by desiccator system having the proper desiccant and which absorb moisture at the control rate and then give the desired relative humidity ok. There are various chemicals which, particular saturated solutions of those chemical at particular temperature, they give particular relative humidity etcetera. And these are normally used in the packaging material that is desiccants etcetera to absorb moisture excessive moisture. And then this in the humidity control systems like in storage areas to maintain appropriate humidity levels etcetera all those things.



So, for measuring all these factors like whether it is time, whether it is rate at the base time, pH and additives and exposure to light, damage, water activity, all these properties there are proper and it becomes very, very important that in the food processing operations etcetrea, that is, one should have a good analysis system, good control system so that the all the required parameters during processing, during handling, during storage that parameter whether it is temperature, whether it is pH, whether it is a water activity or any other thing, this would be properly controlled. Like these all the physical and chemical characteristics of the products you have seen by now they can significantly affect the various changes during processing and storage.

Physical damage can compromise the quality, safety and longevity of the food products. Environmental factors such as composition of the atmosphere during processing and storage of food product is also very important. And then the various instrumentation and control measures are available for ensuring that, yes it becomes, it is not only the chemical reactions may change chemical, but the important thing is that you should properly understand that is what is the causative factor and what is the mechanism. And if both these things are properly understood, and then there should be, you should have something set in place like a proper system to measure these quality factor, the measure, the factor, environmental factor, quality factor, other things; and to measure it, and therefore, also to control, it to monitor it, that is, just as I told you earlier also, that is, if the temperature, pH all the changes should be properly you must be. Even online monitoring, nowadays, there are very advanced system, that is, which are available, even for the online monitoring of the changes in the process, in the conditions of these things, various instruments are there, various systems are there.

Automated system, automated control system etcetera. So, this all should be ensured, this should be placed. In the most of the even modern food industry, they are having all the systems And therefore, they are maintaining, trying to, by understanding the mechanism and the effect of these processes; and with the proper measurement and control systems, quality of the product is maintained; it helps in maintaining the quality.



So, these are the references.

With this, thank you very much for your patience hearing. Thank you.