Novel Technologies for Food Processing and Shelf Life Extension

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Lecture - 40
Shelf Life Extension of Fruits & Vegetables (Respiration & Ripening)

Hello friends. Let us now take up the processing and preservation of fruits and vegetables. In this week, we will devote 5 lectures on fruits and vegetable processing. So, in this first lecture of fruits and vegetables, let us study that principles of Shelf Life Extension of Fruits and Vegetable particularly the Respiration and Ripening processes.

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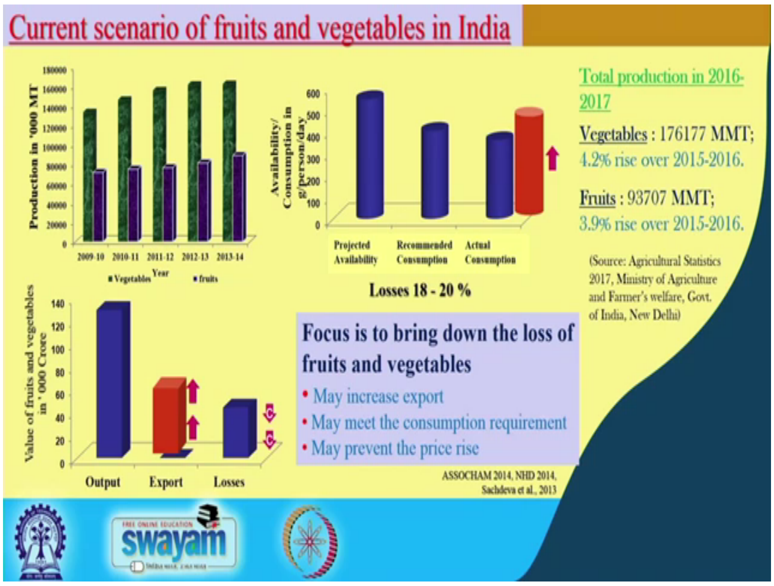

Just in this slide, I have tried to give you an overall picture or current scenario of fruits and vegetables in India. To look here in this first picture that production in million metric ton is given from 2009 and onwards. Total production in the year 2016-17 of vegetables in India was 176177 million metric tons and this accounts for 4.2 percent rise over the production that was in 2015-16. Similarly fruits total production was 93707 million metric tons in the year 2016-17 and this was the about 3.9 percent rise over the production that was done in 2015-16.

So, the production scenario shows that on the basis of that when the availability of the fruits and vegetable is calculated so obviously, on the basis of the production projected availability is much high than that which is recommended for consumption. So, as far our production statistics, we are self sufficient we have sufficient amount of fruits and vegetable even which is required for our daily consumption. But actually if you see the data says that the actual consumption is less than that of the recommended consumption.

So, the main reason for this is the losses which occur in fruits and vegetables that is data says that on an average around 18-20 percent of the produced horticultural produced fruits and vegetable gets destroyed in the value chain.

The; and it results in the losses of the material. It results into the significant loss in the economic terms the country. The data says that more than 50000 crore rupees worth fruits and vegetables are annually lost from the country. Export is significantly less of course, in the recent years there have been increases in the exports of fruits and vegetable and their products. But at present the major focus is to bring down the losses of fruits and vegetables and when we bring down this losses, it may result into availability of the more material. So, actual conjunction may increase even the export of the processed fruits and vegetables or even the fruits and vegetable whole fresh fruits and vegetable may also increase.

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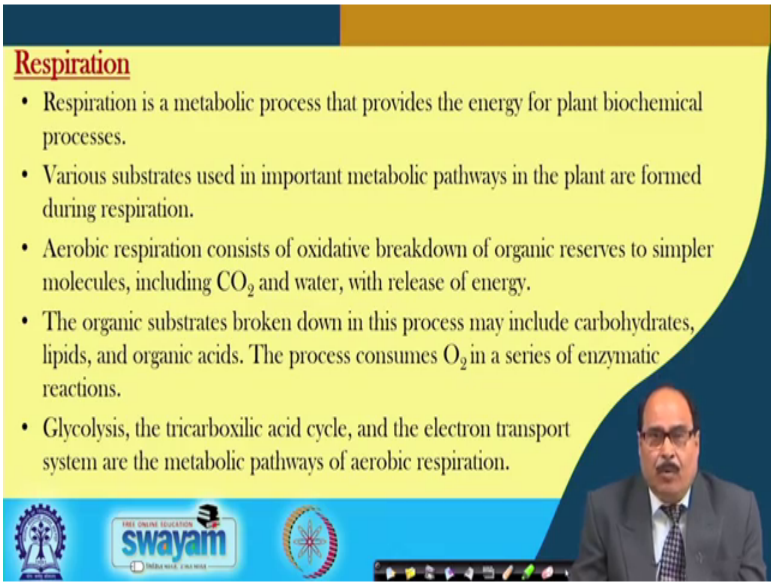

So, the major processes controlling the fruits and vegetable their shelf life include the respiration and ripening. So, let us now understand what are these processes and what are the various factors which govern these processes. As far as the respiration is concerned, it is a metabolic process that provides the energy for plant biochemical processes.

Various substrates used in important metabolic pathways in the plant are formed during respiration. Aerobic respiration consists of oxidative breakdown of organic reserve to simpler molecules including carbon dioxide and water and there is subsequent release of energy.

The organic substrates broken down in the process of respiration may include carbohydrates, lipids and organics acids. The process consumes oxygen in a series of enzymatic reactions. Glycolysis, the tricarboxilic acid cycle, and the electron transport systems are the metabolic pathways of aerobic respiration.

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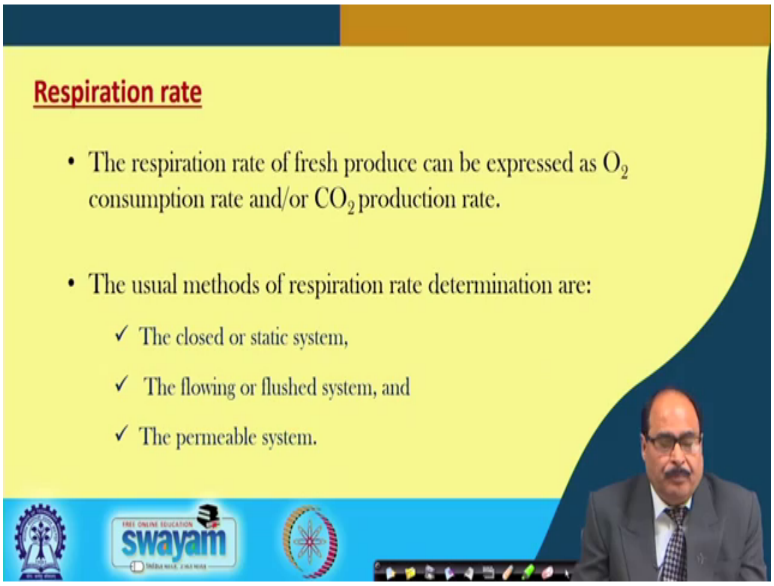

The respiration rate at what rate the respiration process is taking place that will influence both the ripening process as well as the shelf life of the fruit or the changes which take place in the fruits and vegetable.

So, study of respiration rate becomes very very important aspect. So, the rate of respiration is expressed either in terms of O 2 consumption that is the consumption of oxygen rate at which the plant materials consume oxygen and or the rate at which they produce carbon dioxide because these plant material they take oxygen and give out carbon dioxide. So, the usual methods of respiration rate determination include the closed system or a static system; the flowing or flushed system and the permeable system.

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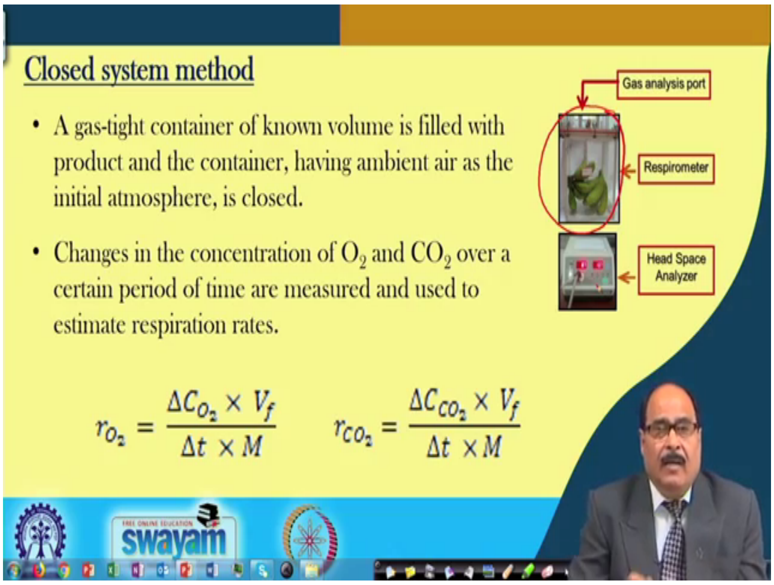

In the closed system as you can see in this figure that there is a container; gas-tight container of known volume. It is filled with the required commodity fruit or vegetable or other plant commodity of which we want to measure the respiration rate.

And inside the container; obviously, the ambient air is the initial atmosphere. After putting the product in the container, the container is a closed; it is made air tight and it is connected to the head space gas analyzer. So, the changes in the concentration of oxygen and carbon dioxide over a certain period of time are measured and used to calculate the respiration rate as per the equation that is provided here in the slide.

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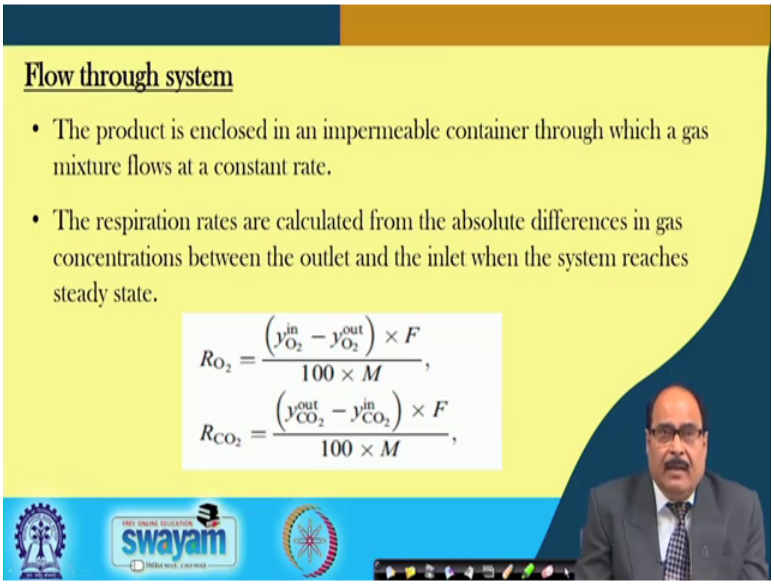

The; in the other method that is the flow through system method, the product is enclosed in an impermeable container through which a gas mixture flows at a constant rate. The respiration rates are calculated from the absolute difference in gas concentrations between the outlet and the inlet when the system reaches a steady state.

And there are the expressions respiration rate of O 2 or respiration of rate of CO 2 are given that is the they are calculated from the absolute differences in the gas concentration.

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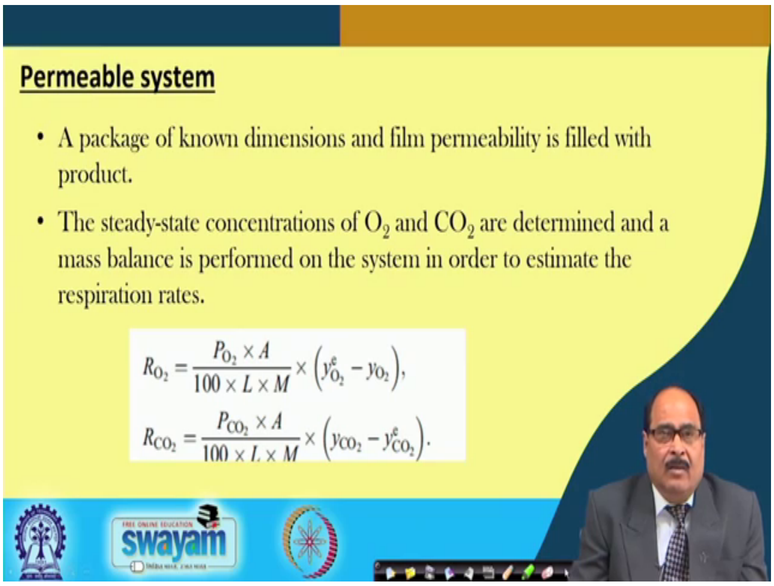

In the permeable system, a package of known dimensions and film permeability is filled with the product and the steady state concentration of oxygen and carbon dioxides are determined and a mass balance is performed on the system in order to estimate the respiration rate. So, here the basically the mass balance of certain at criteria time intervals is the major criteria for the determination of the.

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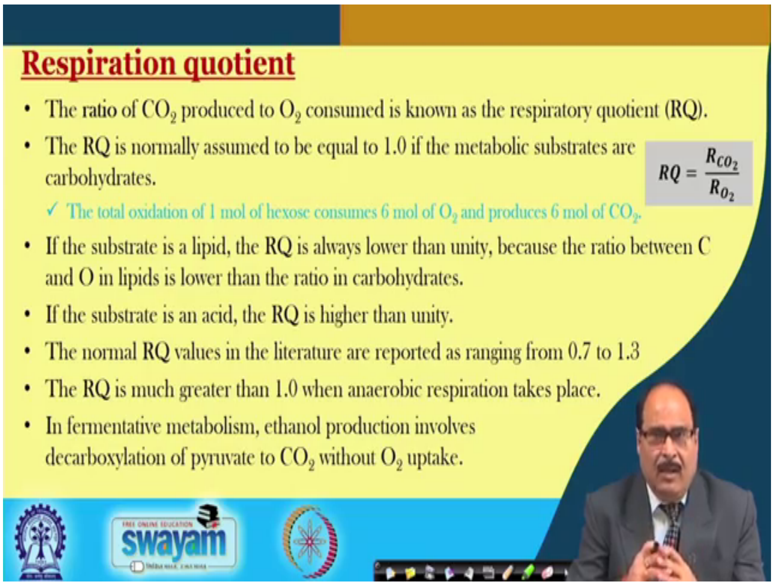

So, after having a studied the respiration rate either on the basis of oxygen consumption or on the basis of carbon dioxide evolution, another important parameter is determination of the respiration quotient and this is actually as you can see here in the there RQ is equal to RCO 2 by RO 2. So, this is the ratio of the carbon dioxide produced to oxygen consumed and the respiratory quotient is normally assumed to be equal that is if the metabolic process or metabolic substrates are carbohydrates; RQ should be 1. That the total oxidation of 1 mol of hexose consumes 6 moles of oxygens an produce a 6 moles of carbon dioxide. So, there is a equal 0 2 and CO 2 ratio. If the substrate is a lipid; the RQ is always lower than the unity because the ratio between C and O in lipids is lower than the ratio of C and O in carbohydrates. If the substrate is an acid, the RQ is higher than the unity. The normal RQ values in the literature are reported as ranging from 0.7 to 1.1 for horticultural produces. The RQ is much greater than 1 when anaerobic respiration takes place. In the anaerobic respiration or in the fermentative metabolism ethanol production involves decarboxylation of pyruvate to carbon dioxide without oxygen uptake. And therefore, the respiratory quotient is much high.

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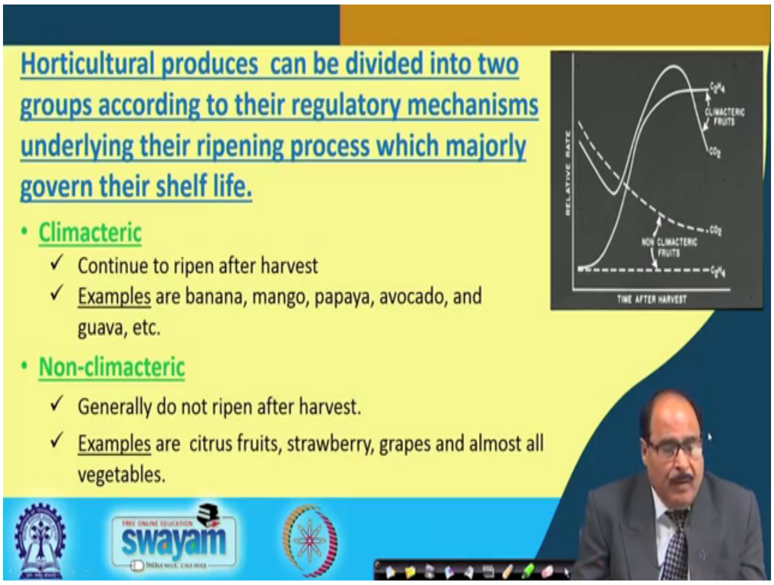

Horticultural produces can be divided into two major groups according to their regulatory mechanism underlying their ripening process which majorly govern their shelf life. You can see here in this picture also that is on the basis of their respiratory behaviour and the rate at which they respire they fruits and vegetable or other horticultural produces are grouped into Climacteric and Non-climacteric.

The climacteric commodities continue to ripen after harvest. Examples are banana, mango, papaya, avocado, guava etcetera etcetera. Non-climacteric horticultural produces generally do not ripen after harvest and example of this category are citrus fruit, strawberry grapes and almost all vegetable.

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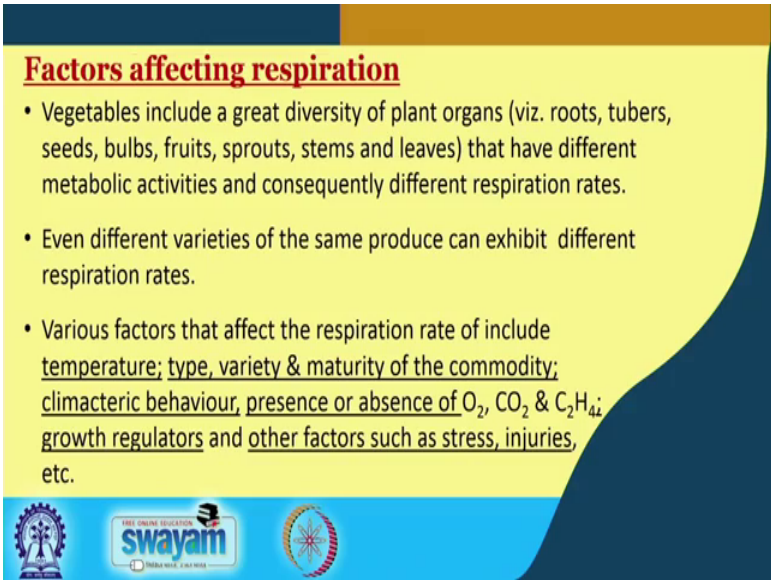

Vegetables this vegetable term include a great variety of plant organs like roots, tubers, seeds, bulbs, fruit, sprout, stem, leaves etcetera and therefore, they have different metabolic activities and consequently they will have different respiration rates even different varieties of the same produce can exhibit different respiration rate.

So, various factors that affect the respiration rate of horticultural commodities include temperature, type, variety and maturity stage of the commodity their climacteric behaviour presence or absence of oxygen carbon dioxide and ethylene or other growth regulators and other growth factors such as stress, injury etcetera to the fruit or vegetable or to the product.

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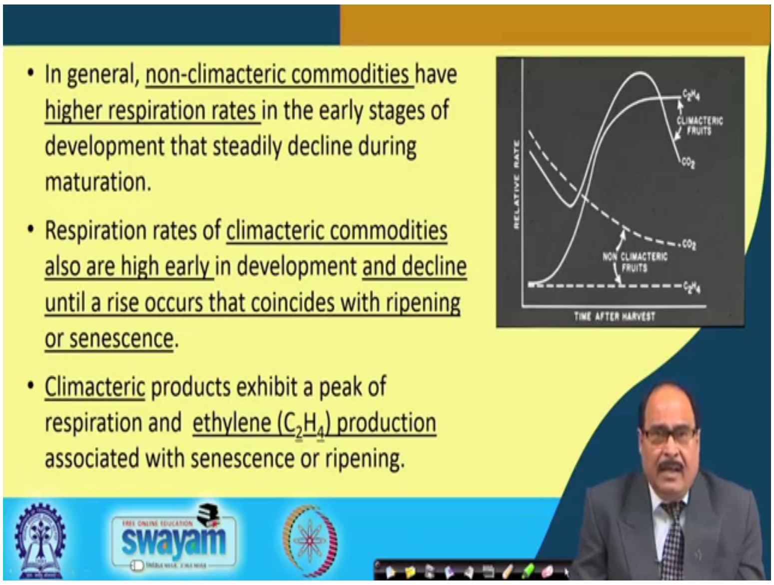

In general, you can see here in this picture that the non-climacteric commodities have a higher respiration rate initially these dotted lines are showing that the respiration rate as well as ethylene production of non-climacteric commodities.

So, initially non-climacteric material has high respiration rate and this with the time after harvest the respiration rate decreases and the ethylene production which is a ripening hormone is almost constant whatever ripen hormone ethylene was getting produced at the time of harvest, it almost the same concentration is maintained. But that in the case of a climacteric materials their respiration is initially high, but it decreases comes to a climacteric minimum that is the climacteric minimum here at the target at the point. When you see ethylene production also if you see in this case, it was initially less and then it increases means that is there is a consequent sometime that is the climacteric minimum which it reaches at that time the ethylene production increases.

And that is the point where the ripening of fruits ripening process of the fruit starts and this respiration and because of this there is a significant increase in the respiratory behaviour of the climacteric fruits. It reaches to a point that is the climacteric maximum this period point is known as climacteric minima, this point is known as climacteric maxima. And during this period of a climacteric rise, there are several significant changes which are brought in the fruits and vegetable that we say that is the fruit is ripening that is the ripening process of the we will come to that this aspect little later.

So, and at this point when it the you can say that; at this point the fruit is of maximum eating value and here the senescence is sets into at this climacteric minimum point the ripening starts, at the climacteric maxima point the at ripening stops and the fruit has maximum eating value and at this point the it starts a spoiling that is senescence sets into and finally, after sometime. So, there is a relationship between the ethylene production and ripening and finally, the senescence.

So, climacteric produces exhibit a peak of respiration and ethylene production associated with the senescence and ripening; I already explained to you.

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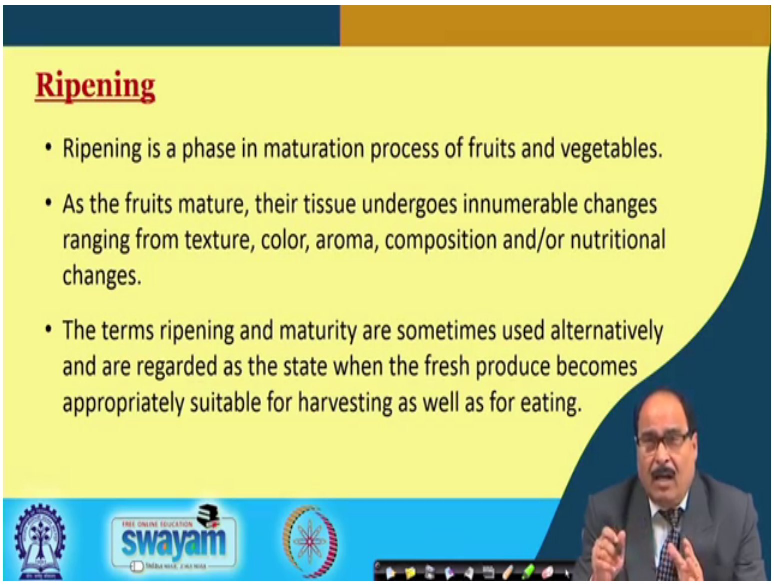

So, now that is the respiration as you have seen in the climacteric fruits; respiration is that is the associated it results into the ripening that period. So, ripening is the phase in maturation process of fruits and vegetable. As the fruits mature, their tissues undergoes innumerable changes ranging in the change in the texture, color, aroma, composition and or other components of the material including the nutritional changes. The term ripening and maturity are sometimes used alternatively and are regarded as the state when the fresh produce becomes appropriately suitable for harvest as well as for eating.

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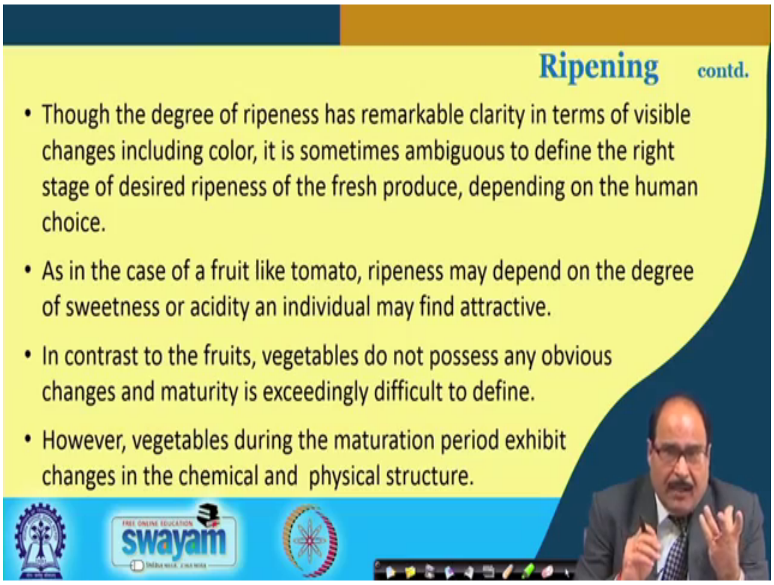

Though the degree of ripening or degree of ripeness has remarkably; remarkable clarity in terms of visible changes including color and other attributes. It is sometimes ambiguous to define the right stage of desired ripeness of the fresh produced depending upon the human choice. As in the case of fruits like tomato; ripeness may depend on the degree of sweetness or development of acidity; an individual may find attractive. Some people might like sweet taste of the tomatoes, some people like good red color of the tomato, some people like that acid of the tomato.

So, and these colors and acid etcetera are formed during ripening process. So, it depending upon the individual perceptions one can accordingly define that what is thefiner or correct stage of ripening. In contrast to the fruits; the vegetables do not possess any obvious change and maturity is exceedingly difficult to define. However, vegetables during the maturation period exhibit changes in the chemical composition, physically structure, textural changes, some softening etcetera may takes place sometime; lignification or hardening of the vegetable also may take place.

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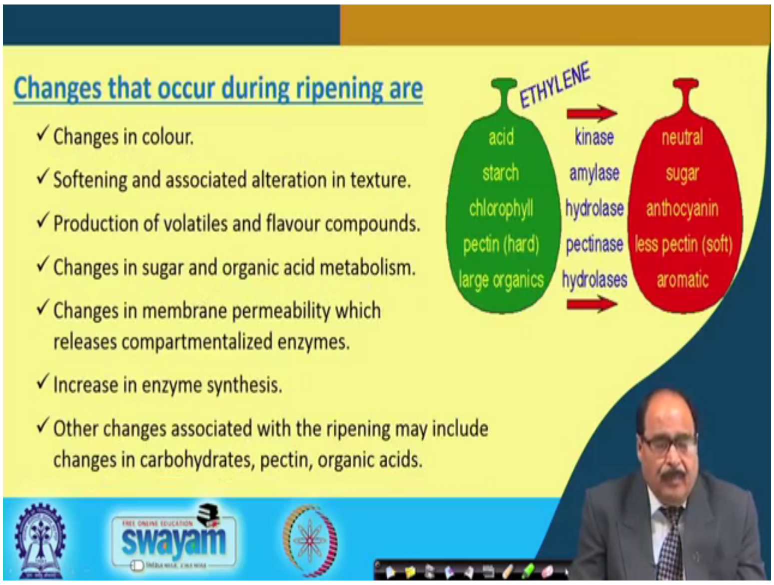

So, the changes that take place during ripening of the fruit are those in the colour, there may be softening and associated, alteration in texture, production of volatiles and flavor components changes in sugar and organic acid metabolism. That is the sour fruit may change into a sweet; intensively sweet commodity are fruit after ripening, changes in the membrane permeability may takes place which releases compartmentalized enzymes and these enzymes that is a facilitates the ripening process or other physiological processes. Even there may be some increase in the enzyme synthesis, new enzymes or new hormones etcetera also might be produced during the ripening process. Other changes associated with the ripening may include changes in carbohydrate, pectin, organic acids and so on.

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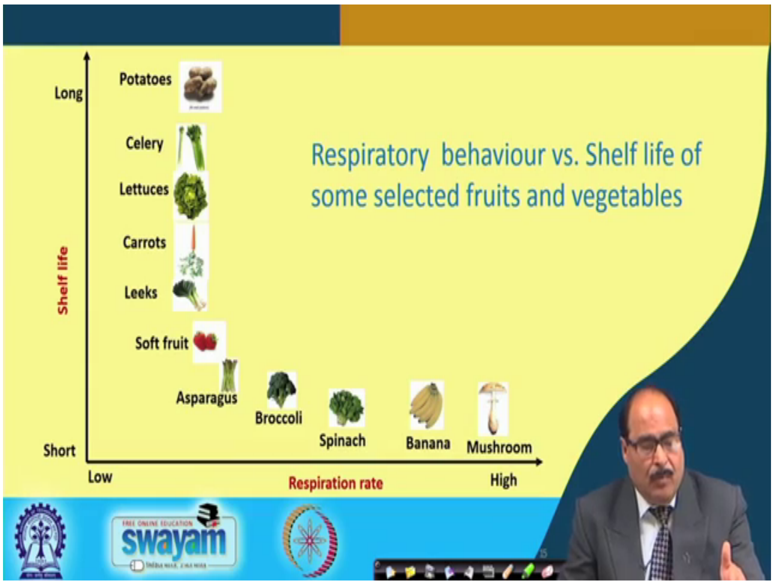

So, the respiration rate as I told you earlier is directly related to the shelf life of the materials. In this graph I have shown that some that is shelf life of some fruits or vegetable and their relationship with the respiratory. You can see that is the in the x axis, it is the respiration rate from low to high it is going. So, the mushroom which has got a high rate of respiration, it has comparatively lower shelf life in the y axis is the shelf life from short to long.

Potato; you can see the vegetable and the extreme ends of both that is the in the y axis that is the potato which has a comparatively lower rate of respiration among all these commodities which we have been take here. So, it has low rate. So, it has high or long shelf life.

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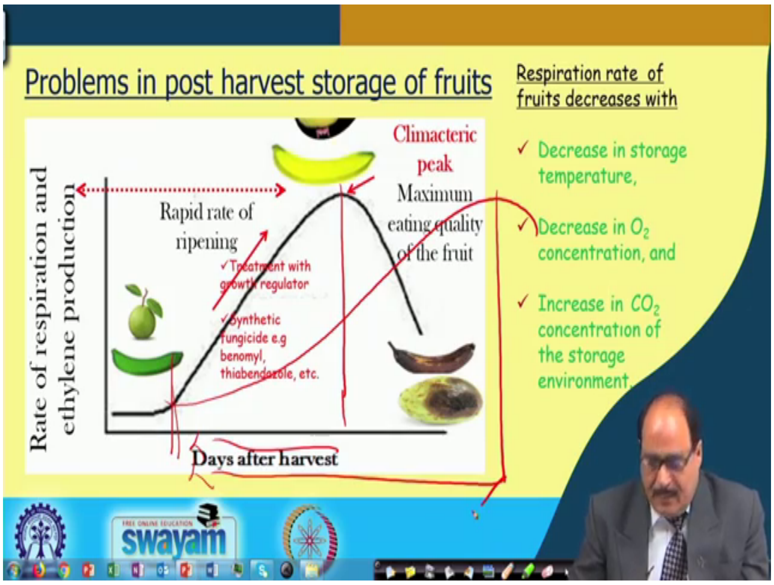

So, now; after having this brief understanding about the respiration and ripening processes, let us see that what are actually the problems in post harvest storage of fruits or the vegetables.

So, in this slide we have seen that is a respiratory behaviour and you can see that as I explained earlier that this is the climacteric minimum and this is the climacteric maximum. At this point if the fruit has got that is the ripening starts here, it is completely ripened, all the changes associated with the ripening are completed and the fruit is in good state of quality at state right. So, you can say in this way that this is a this line; this is the shelf life of the fruit; that is here if this is the period after hard definite period after harvest and between before the consumption during which the food is shelf life.

But what happens that during this when the fruits or vegetables ripen that is they depending upon the as you have seen in the earlier slide this a first (Refer Time: 23:48) commodity which have high respiration rate, they have short shelf life and the short shelf life leads to the a spoilage of those material. So, somehow by appropriate means we need to increase the shelf life means somehow by one or other means we have to decrease the rate of respiration right.

So, for doing this even there to decrease the rate of respiration and to make sure that is the fruits and vegetable they have little more shelf life , these industries or farmers or other agencies they treat with some growth regulators etcetera that is the hormone which are ripening hormone, ethylene produces here, then they treat the commodities with this. And in the process some time even synthetic fungicides like benomyl, thiabendazole etcetera are treated.

So, these are carcinogenic material and they produce some undesirable changes. So, shelf life may increase, but this the product commodity may not be safe for the consumption. So, the normal for is to manipulate the respiration rate of respiration by other means like you have seen that is the factors which influence the respiration rate are the gaseous composition temperature. So, particularly the respiration rate of the fruit decreases with the decrease in a storage temperature that it decreases with decrease in oxygen concentration and increase in carbon dioxide concentration of the storage environment.

So, by manipulating the carbon dioxide and oxygen compositions in the environment surrounding these fruits and vegetables as well as by manipulating the temperature lowering down the temperature, ee can reduce the shelf life, you can reduce the respiration rate and accordingly that is this life which was here that is the slope of this life can be reduced. And therefore, the life can be extended from this point you can see here in this.

And that is the basic principle which is followed in the for the extension of shelf life of fruits and vegetables appropriate methodologies are used to manipulate the respiration of fruits and vegetable after they are.

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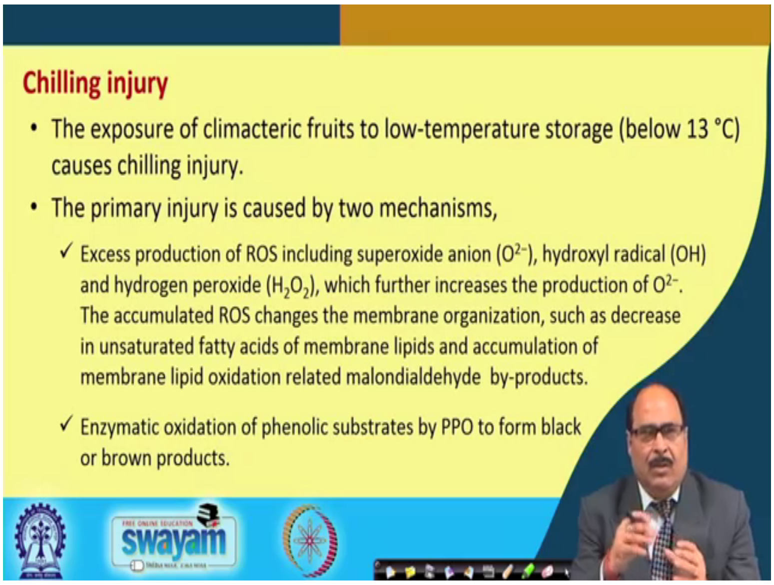

So, I will come little later to this; before that that is if the fruits and vegetables they are not stored in proper manner, it may result into different disorders, metabolic disorders and one major disorder is the Chilling Injury; that is exposure of the climacteric fruits to low temperature storage below 13 degree Celsius are that causes chilling injury.

Even the banana etcetera banana if it is put in the refrigerator blackening of the banana may take place. So, similarly there are many other examples. So, the primary reason caused for chilling injury that is they are the primary injury maybe because of the two processes mechanisms that is excess production of ROS including superoxide anion, hydroxyl radical, hydrogen peroxides etcetera which further increases the production of superoxide anion. The accumulator ROS changes the membrane organization such as decreases in the unsaturated fatty acids of the membrane lipids and accumulation of membrane lipid oxidation related malondialdehyde by-products etcetera and these result into the visible changes on the surface of the fruits etcetera.

Even enzymatic oxidation of phenolic substrate by PPO to form black or brown products or the other mechanism which cause chilling injury.

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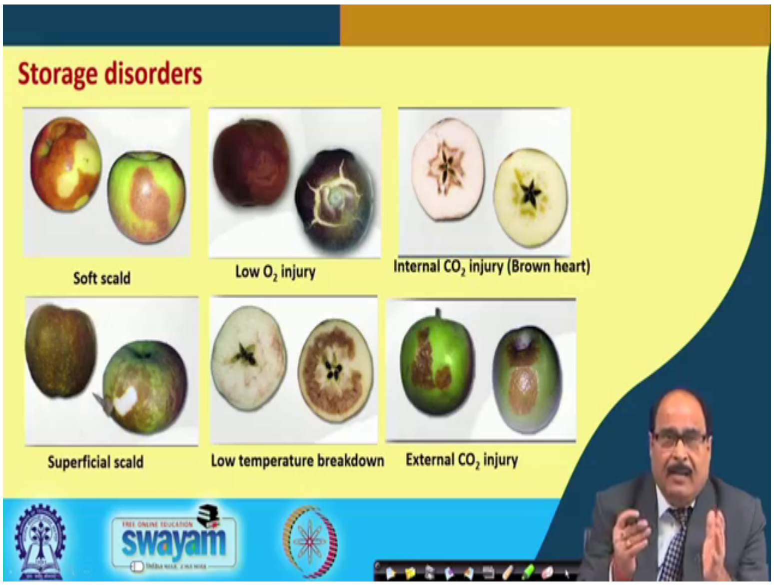

And in this, you can see the different storage disorders of fruits like soft scald, low oxygen injury, internal CO 2 injury, superficial scald, low temperature breakdown, external CO 2 injury etcetera how they are look like right.

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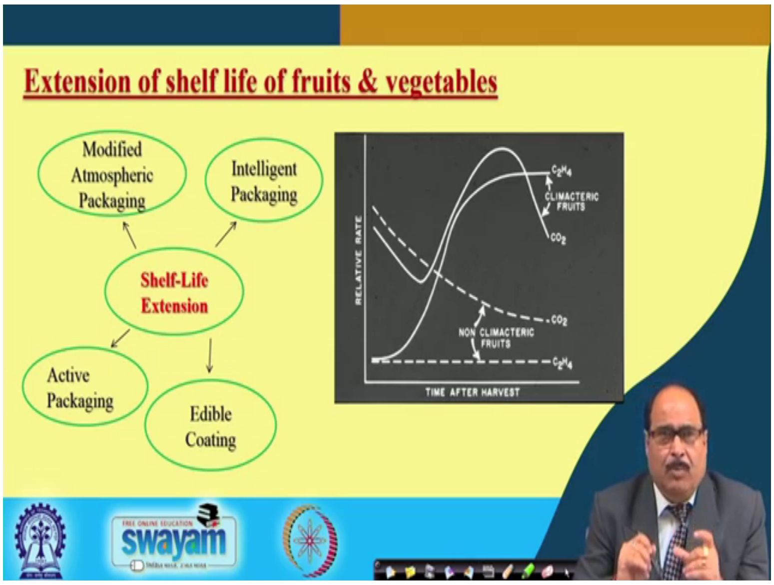

So in fact, for extension of shelf life as I told you earlier that is there are different methods. In fact, here the novel method; I will be discussing for that and in all these processes in one or the other way we manipulate the rate of the respiration.

So, the methods for manipulation of the rate of the respiration of fruits and vegetable and therefore, for extension of shelf life includes modified atmosphere packaging or controlled atmospheric storage ,intelligent packaging, active packaging edible coating etcetera. So, see these are the some of the novel methods

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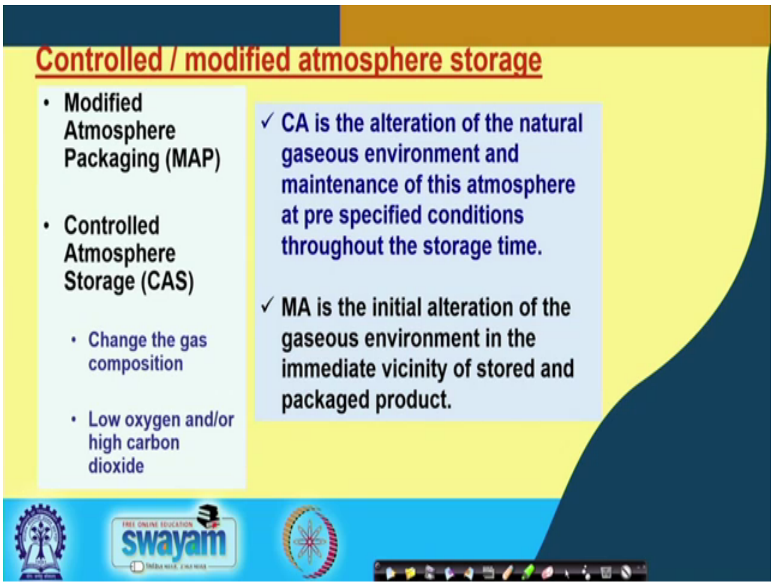

So, although in the next lectures in th series we will be taking up this topics separately some of these topics, but today I will just like to give you briefly the concept in each case Modified Atmosphere Packaging or Controlled Atmosphere Storage as I told you it is the changes in the gas composition normally oxygen is lowered down and carbon dioxide is increased.

Control atmosphere is the alteration of the natural gaseous environment and maintenance of this atmosphere at pre a specified conditions throughout the storage time whereas, the modified atmosphere is the initial alteration of the gaseous environment in the immediate vicinity of a stored and packaged product.

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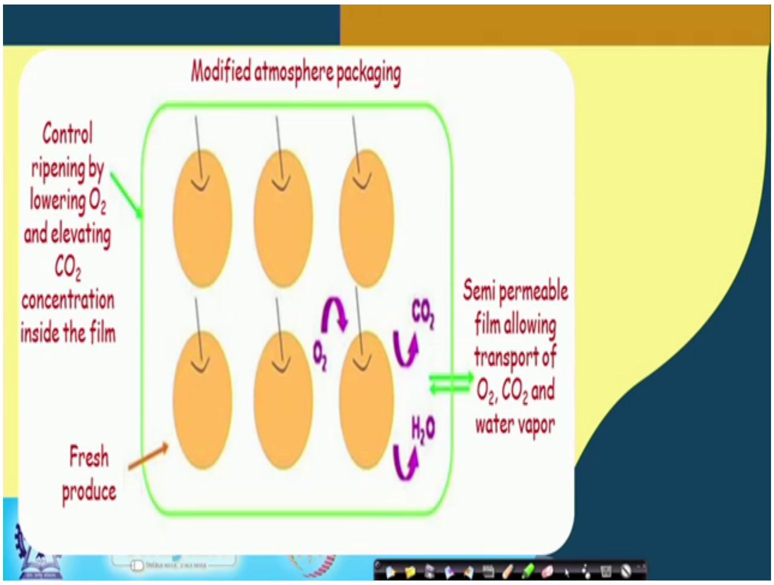

Modified atmosphere packaging as you can see here in this picture. We saw, I explained you that when the commodities they respire, they consume oxygen, they give carbon dioxide and also some water is produced. So, they give out water. So, it means that is in the atmosphere in the vicinity of the fruits and vegetables the environment changes oxygen normally becomes less, carbon dioxide concentration becomes more and water concentration becomes more.

So, what is done in modified atmosphere packaging? Having appropriate means suitable packaging material another film like semi permeable films etcetera are taken to pack these fruits or vegetable alright and these semi permeable membrane that is they have that is we need to select it in a proper manner which having suitable permeability that is there to oxygen permeability to carbon dioxide their permeability to water vapor. So, that they allow that is the control transport of these gases in and out of the and finally, we; by this process we maintain a desired O_2, CO_2 and water composition inside the environment around the packet.

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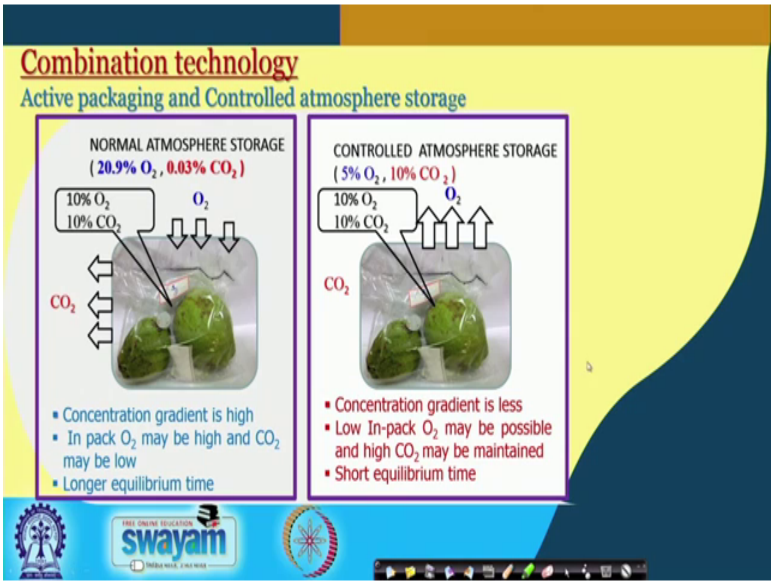

So that is the concept of modified atmosphere packaging. We will take up this further in the next lecture in detail and a combination technology another novel concept that is the combination of active packaging and controlled atmospheric storage. Let us see that if in the normal atmosphere there is about 20.9 percent oxygen and 0.03 percent carbon dioxide.

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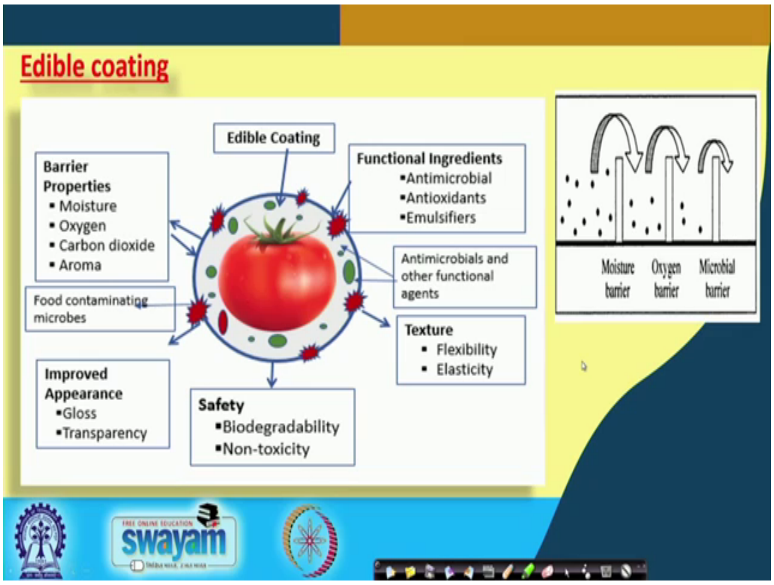

And we want that for the controlled atmosphere there is a about we want that oxygen should be maintained to 10 percent and carbon dioxide should be maintained to 10 percent means that is carbon dioxide has to be increased from 0.03 to 10 and O 2 has to be brought from 20.9 to 10.

So, it means that is the concentration gradient is very high it may take long time for the establishment of desired environment inside the package and therefore, it may take even longer time for equilibration and during this period itself the fruits and vegetable may have significant changes, its quality might have change. Another case if you see that there is a condition where the by other means the atmosphere surrounding that is the atmosphere gaseous composition in the storage atmosphere is changed to 5 percent O 2 and 10 percent CO 2 by some mechanical means and all those right.

And so, in this case that is 10 percent CO 2 is already maintained. So, it is there the 10 percent O 2. So, from 5 percent to 10 percent we need to bring. So, here it becomes easier that is the since concentration gradient is less it is low in pack O 2may be possible and high CO 2 may be maintained. So, it takes short time comparatively in lesser time the equilibrium required equilibrium gaseous composition etcetera is achieved.

So, the material quality and so, it has both together. It has a we get the comparatively higher shelf life; longer shelf life of the material. Similarly there is a edible coating technology, we will also take up in the active packaging. We are using impermeable or selectively permeable materials packaging material. We are packing here in the edible coating some food grade materials etcetera are applied on the surface of the fruit or vegetable.

The basic principle here it also to make sure that is the movement of the gaseous that is oxygen from outside to inside (Refer Time: 34:54) and CO 2 from inside to outside that (Refer Time: 34:58) that is controlled and accordingly the rate of respiration is controlled and shelf life. Edible coating also, we will take up separately the details.

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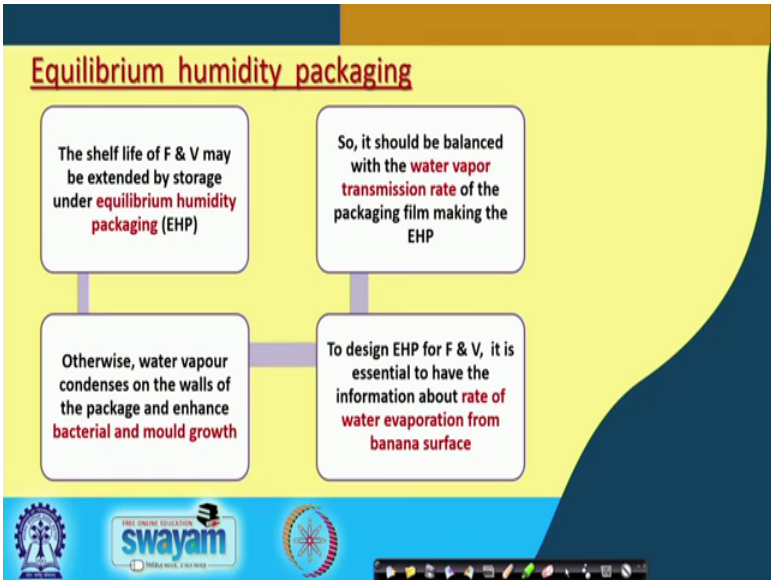

Another important concept is Equilibrium humidity packaging. As you have seen in the respiration rate that this when respire, they release CO 2 and H 2 O water. So, this water inside the packet and water outside the packet; that is humidity inside the packet;, environment inside the packet as well as in the extra environment outside the packet in the storage environment.

One should have proper equilibrium that is it should equilibrium otherwise. If the equilibrium outside the storage environment is more or inside the because inside this when the fruit is respiring water is getting released and if the outside is also more, then water from inside it may not go out or if it is inside it is less. So, from outside it may come in so, it may result into the condensation of the moisture inside the packet and this condensed moisture may act as a vector for the bacterial growth and fungal growth etcetera and it may result into the spoilage of the fruits and vegetable.

So, it is a very very important aspect that the packaging material etcetera are taken in such a way calculations are done and it is actively packaged moisture is scavengers etcetera. Taken to consider and efforts we made that the relative humidity of the environment outside the package, inside the package, around the food there is a equilibrium is maintained and if they equilibrium is maintained it will avoid the condensation of the moisture ok. So, to design equilibrium humidity packaging for fruits and vegetable, it is essential to have the information about the rate of water evaporation from the fruit surface or you can say banana surface we have done. studies and this respect and banana and guava etcetera to large extent and so, it should be balanced with the water vapor transmission rate of the packaging film making the equilibrium humidity packaging and it gives better shelf life further.

So, with this, I thank you for your hearing in the; by now I hope you have got good understanding about the ripening process, respiration process, how fruits and vegetable getting spoil etcetera and what are the different methods by which their shelf life can be increased. So, in the next classes, we will take up these methods one by one in little detail.

Thank you.