Post-Harvest Operations and Processing of Fruits, Vegetable, Spices and Plantation Crop Products

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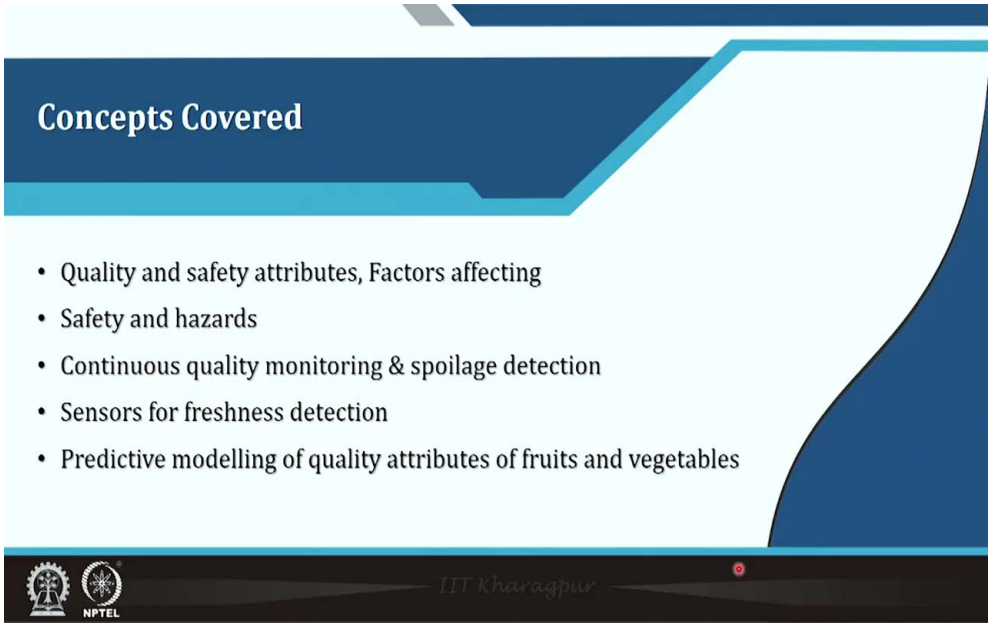
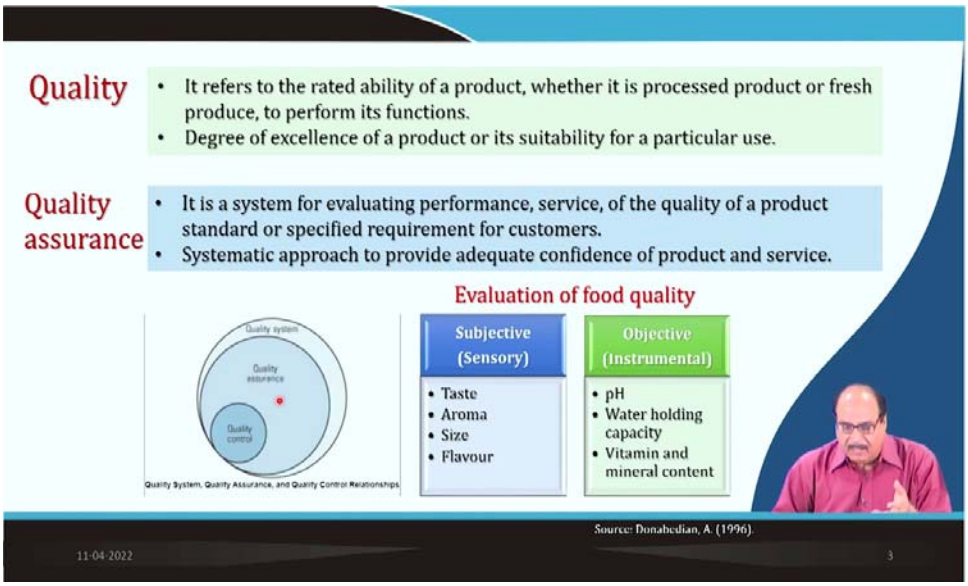
Lecture 10
Quality Assurance and Control (QA/QC)

In this lecture the various aspects of quality assurance and quality control protocols will be discussed.



The concept covered of this lecture includes quality and safety attributes of fruits, vegetable and other related commodities, various factors which influence the quality and safety, safety and hazards and after that continuous quality monitoring and spoilage detection as well as

various sensors which are used for the detection of freshness in fruits and vegetables and the discussion about predictive modeling of quality attributes of fresh fruits and vegetables.

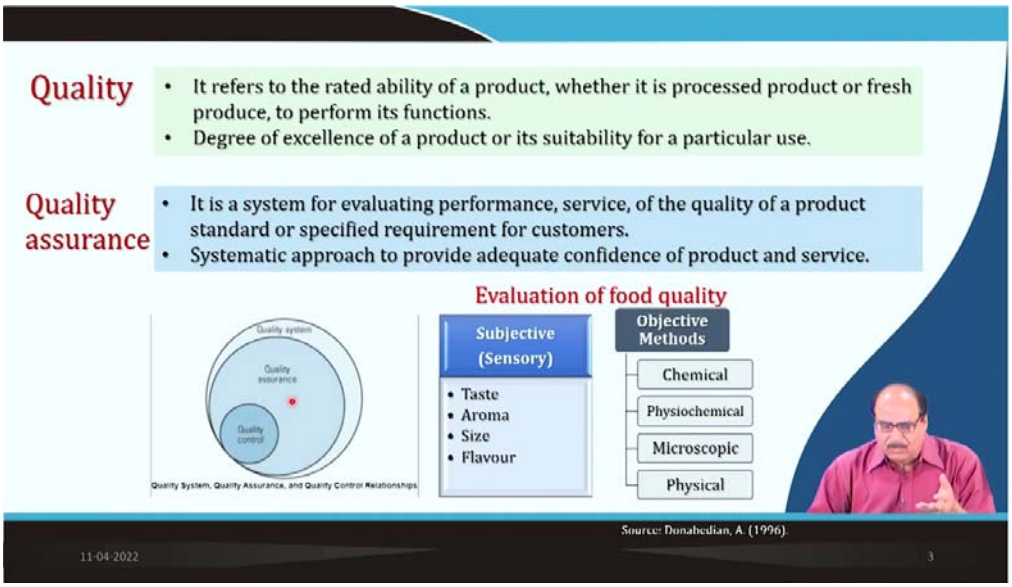


Quality and quality assurance

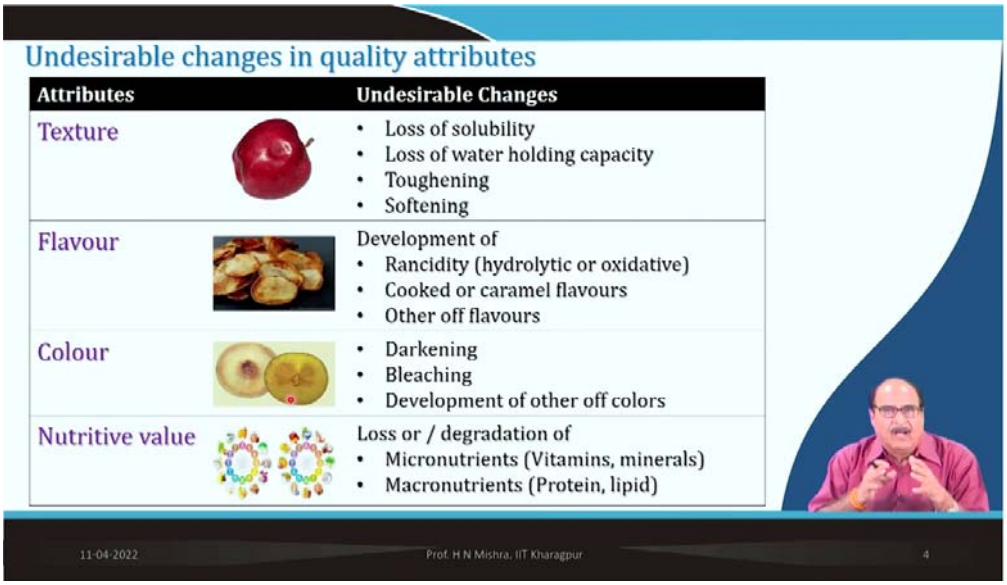
The quality of a material refers to the rated ability of a product, whether it is processed product or fresh produce; to perform its functions, proper functions. Quality assurance is a system for evaluating the performance service of the quality of the product standard or a specified requirement for customers.

It is a systematic approach to provide adequate confidence of product and service. Quality system includes quality assurance and quality control and their relationship. However, quality system is a bigger umbrella, which includes quality assurance and quality control. For the evaluation of the quality of a particular fruit, vegetable or any other food there are two types of methods one is the objective assessment other is the subjective assessment.

Subjective assessment generally includes the sensory evaluation or sensory attributes like taste, aroma, size and flavor. In the objective method, generally instrumental approaches are used and various instruments are used for measuring the quality attributes like pH, water holding capacity, vitamin and mineral content etc.



These objective methods may be further categorized into chemical method, physiochemical method, microscopic method or physical methods.

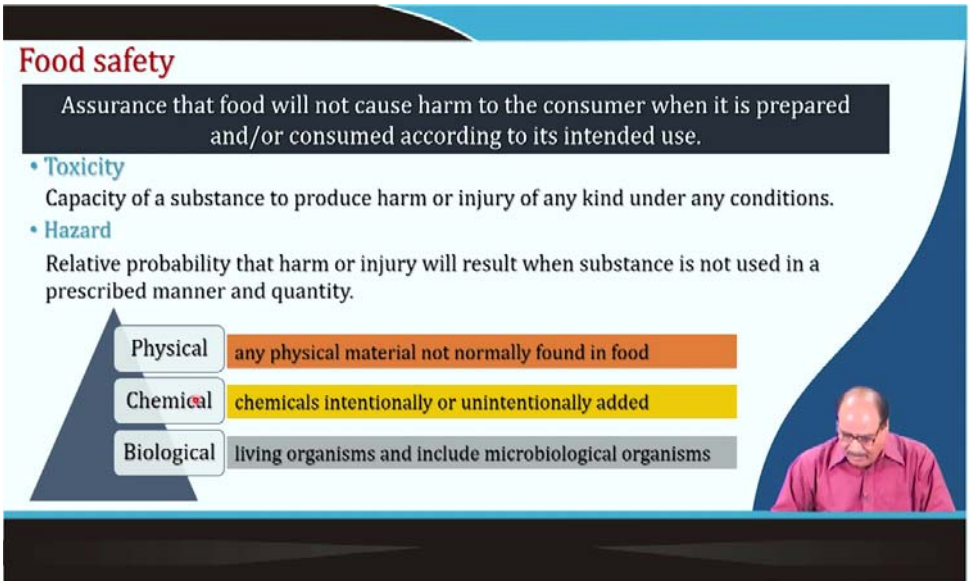


Undesirable changes in the quality attribute

There are various undesirable changes in the quality attributes like in the texture, there may be loss of solubility, loss of water holding capacity, the material may become soft or it may become tough depending upon the various reactions and process which are undergoing in these commodities.

Similarly, regarding flavor there may be development of rancid flavor either hydrolytic rancidity or oxidative rancidity depending upon the nature of the material that may be cooked or caramel flavors, other off flavor development. Like for colour, the commodity may become dark or it may become bleached or a new color may come or there may be development of off colors.

Similarly, nutritive value of the commodity may also get changed and it because of either loss or degradation of micronutrients like vitamins, minerals and macronutrients like proteins and lipids.



Food safety

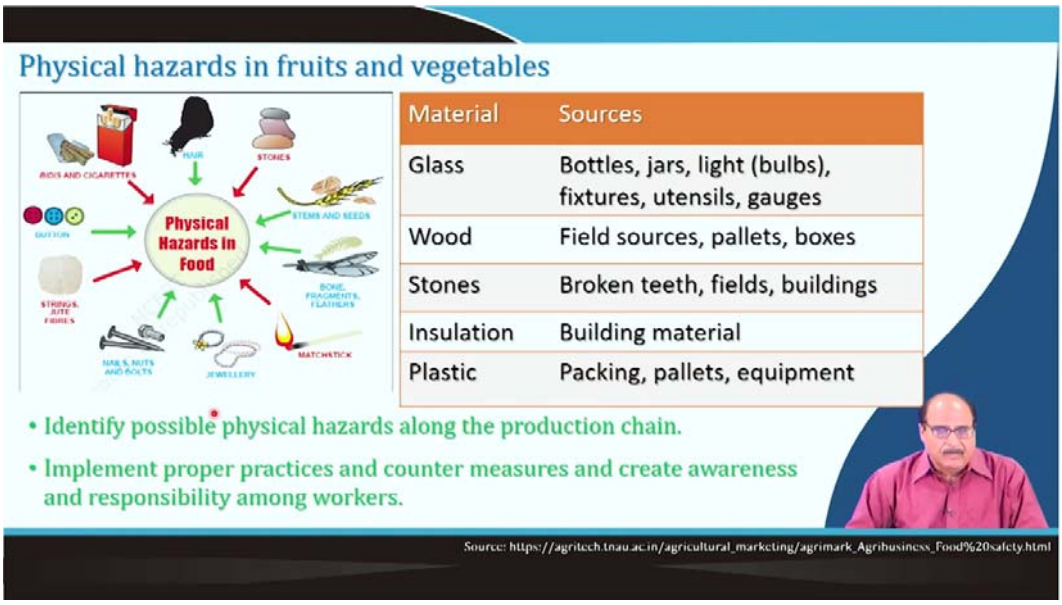
Food safety is the assurance that food after we eat, it will not cause any harm to the consumer. The food will not cause any harm to the consumer when it is prepared or consumed according to its intended use.

Toxicity is capacity of a substance to produce harm or injury of any kind under any conditions. Hazard is the relative probability that harm or injury will result when substances are not used in a prescribed manner or in a prescribed quantity. The hazards may be physical, chemical or biological hazards.

Physical hazards: Any physical material which is not normally found in food.

Chemical hazards: Chemicals which may be intentionally or unintentionally added to the food.

Biological hazard Living organisms and various microbiological agents like bacteria, molds in the food.

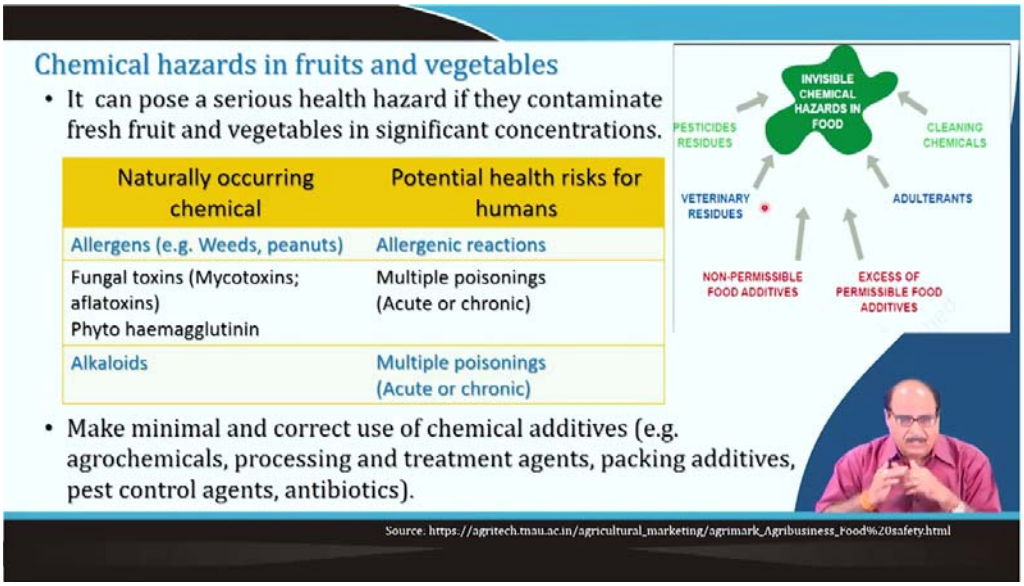


Physical hazards, in fruits and vegetables

Physical hazards, in fruits and vegetables, include various materials. The examples of few physical hazards are as follows:

- ***Glass*:** This may come from the various sources like bottles, jar or light bulb, fixtures, utensils, gauges etc.
- ***Wood:*** Comes from the field or pallets or boxes which are used for packaging of the material.
- ***Stones:*** Food may have stones from sources like broken teeth, fields or buildings etc. ***Insulation****:* This is from building materials
- ***Plastic:*** It is the packing, either in pallets, comes from various equipments etc.

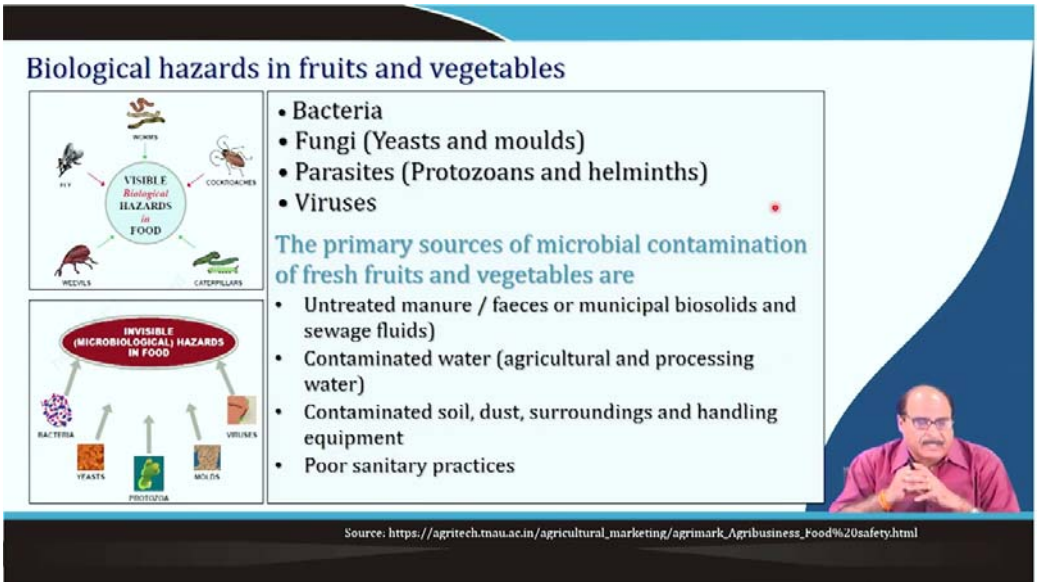
These are the various sources from which physical hazards may come into the fruits and vegetables. So, we have to identify the possible physical hazard along the products and chain and implement proper practices and counter measures and create awareness and responsibility among the workers to ensure that the commodity is free from any such physical hazards.



Chemical hazards

Chemical hazards may be found in fruits and vegetables and they can pose a serious health hazard if they contaminate fruits and vegetables in significant concentrations. There are many commodities there are naturally occurring chemicals like allergens found in the weeds or peanuts. Allergic reactions sometimes lead to severe and serious health problems. Similarly, multiple poisoning either acute or chronic may be caused by fungal toxins present in the materials like mycotoxins, aflatoxin or phyto-haemagglutinin. Alkaloids present in the food material also cause on multiple poisoning, either acute or chronic.

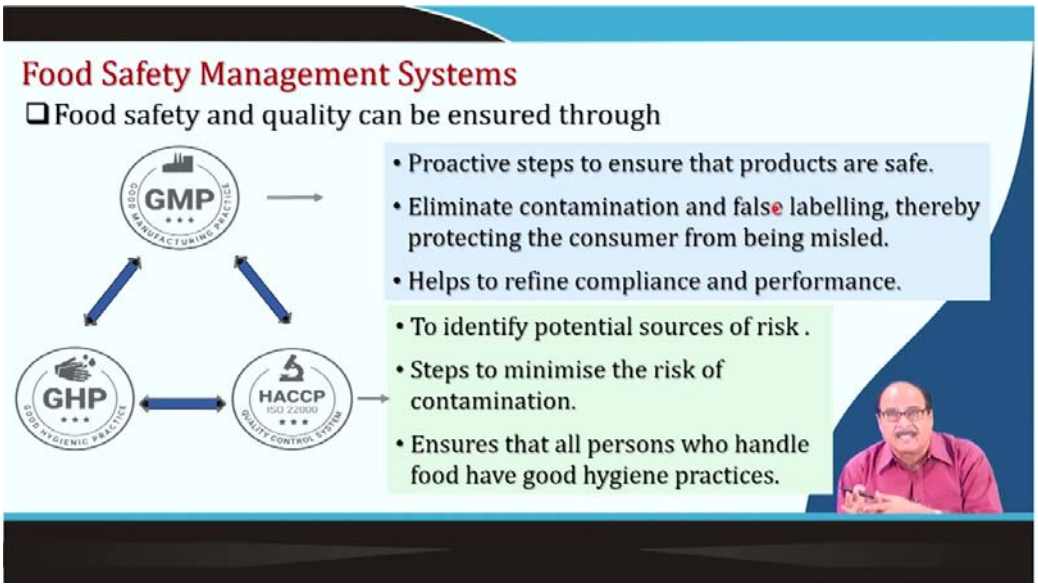
There should be minimal and correct use of chemical additives. The thumb rule is to reduce chemicals during processing as far as possible or use of chemical in any food may be avoided. However necessary minimum possible concentration of chemical to be allowed in agrochemicals, processing and treatment agents, packing additives, pest control agents and antibiotics etc.. If these chemicals are used in excessive quantity or they readily remains in the food material and may induce a potential health hazard.



Biological hazards in fruits and vegetables

Similarly, biological hazards in fruits and vegetables may include contamination with bacteria, fungi like yeast, and molds or parasites like protozoa and helminthes or viruses. So, the primary sources of microbial contamination are fresh fruits and vegetables are as follows:

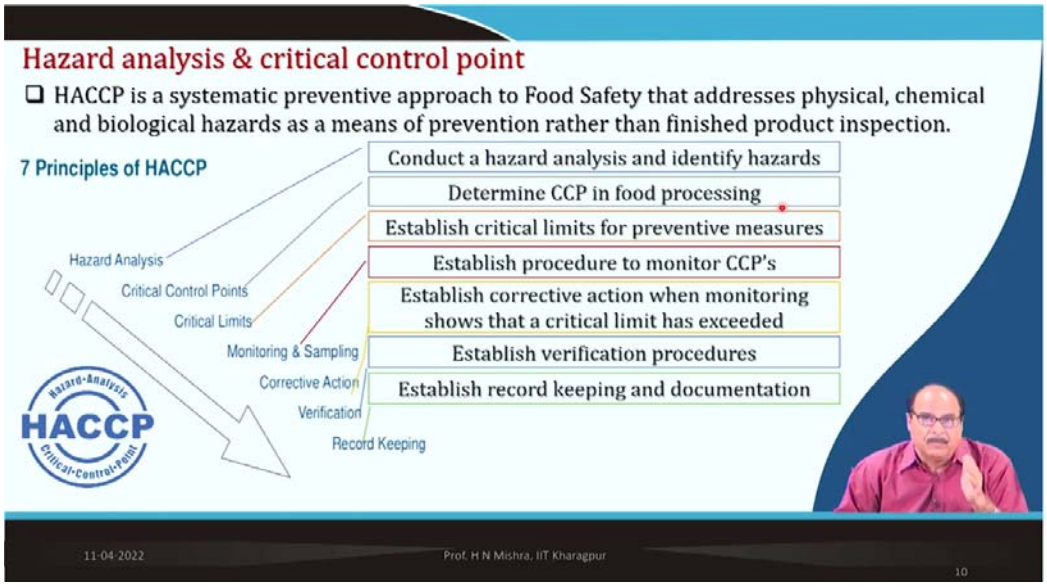
- ***Untreated manure or faeces or municipal biosolids and sewage fluids*** are accumulate by the plant if not treated properly. The contaminant through the plant comes into the fruits or vegetables.
- If ***contaminated water*** is used either in the agricultural field or for processing. The contaminated water will be another source of biological hazard.
- ***Contaminated soil, dust, surroundings, and poor handling of equipment.***
- ***Poor sanitary practices*** in the field as well as in the processing plant or where the equipment or the material or where it is being handled.



Food safety management

The food safety management system includes food safety and quality can be ensured through implementing of proper ***Good Manufacturing Practices (GMP), good hygienic practices (GHP)*** *and* ***Hazard Analysis and Critical Control Point (HACCP).*** GMP ensures that products are safe, it eliminates contamination and false labeling, thereby protecting the consumer from being misled.

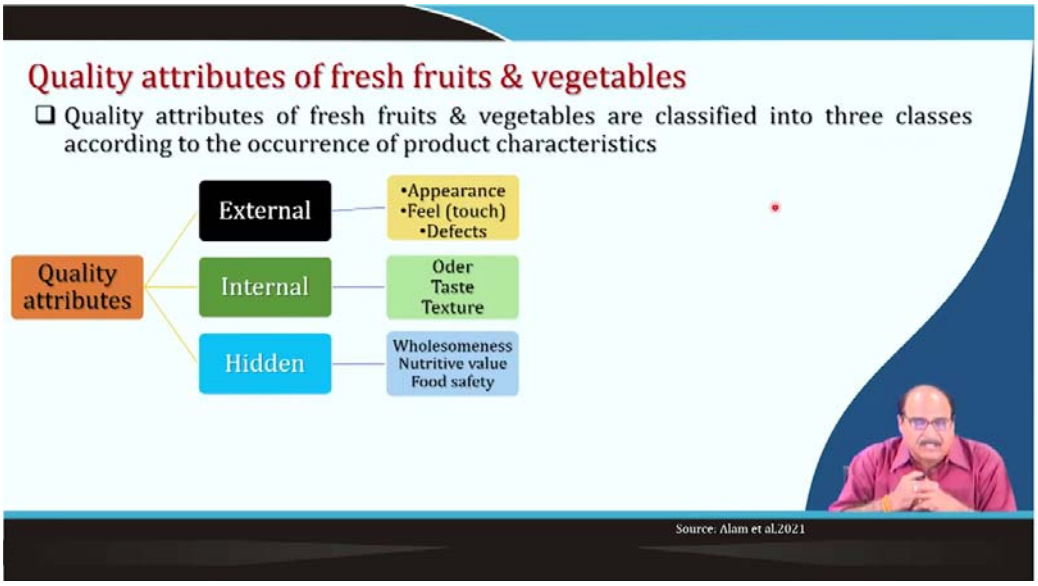
GMP also helps to refine the compliance and performance. GHP and HACCP are used to identify potential sources of risk, they are the steps to minimize the risk of contamination. It ensures that all persons who handle the food have good hygienic practices or they absorb good hygienic practices.



Hazard Analysis and Critical Control Point (HACCP).

As previously mentioned, hazard is a systematic preventive approach to food safety that addresses physical, chemical and biological hazards as a means of prevention rather than finish product inspection. There are seven chronological steps of HACCP is commonly known as 7 principles of HACCP, which includes

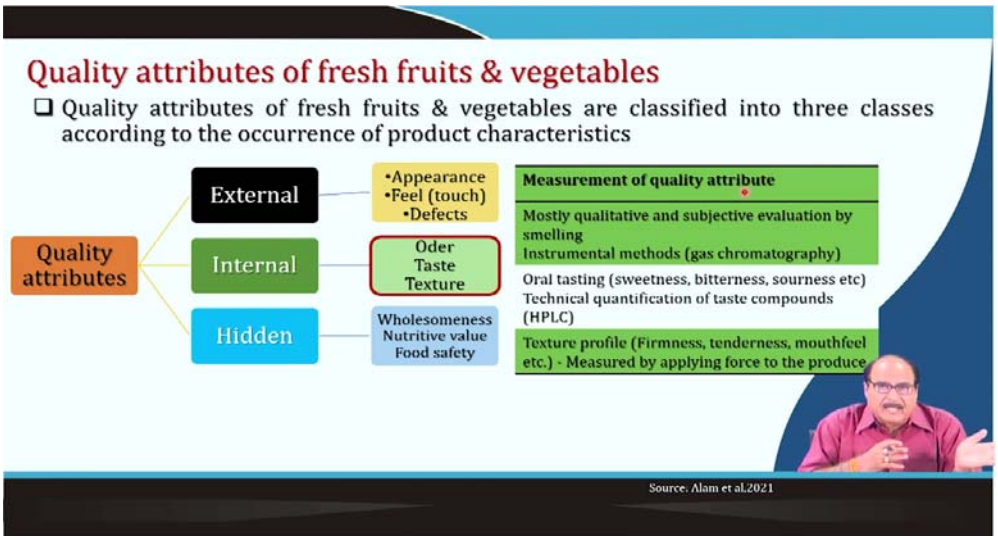
1. Hazard analysis i.e conducting a analysis and identify the potential hazards
2. Determining the CCP. The critical control point in the food processing is crucial in value chain.
3. Establishing critical limit for preventive measures
4. Establishing a procedure to monitor that CCP.
5. Establishing a corrective action that is when monitoring shows that a critical limit has exceeded. If it has not been followed or implemented properly then what should be corrective action
6. Finally establish verification procedure that whether CCPs are in proper order in value chain, are properly monitoring is in force or not
7. Documentation and recording of everyday procedure and easy retrieval of the data.



Quality attributes of fresh fruits and vegetables

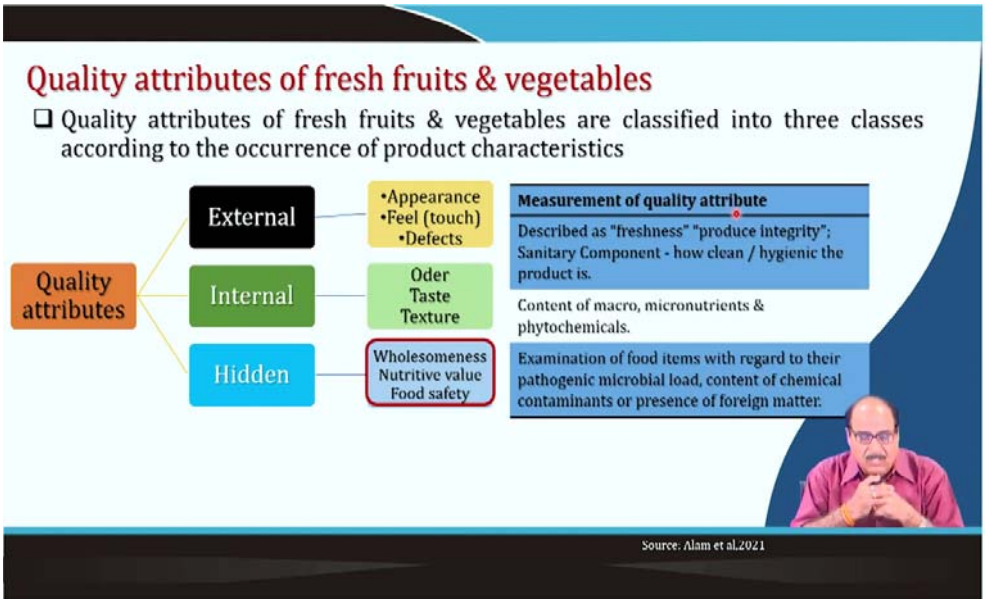
As far as the quality attributes of fresh fruits and vegetables are concerned, they can be classified into three groups according to the occurrences of the product characteristics like it may be external quality attribute, internal quality attributes or hidden quality attribute.

External quality means appearance, feel, touch or such other defects and it can be measured either by visual evaluation of size, shape, gloss and colour or there are visual guides and with the help of colorimeters.



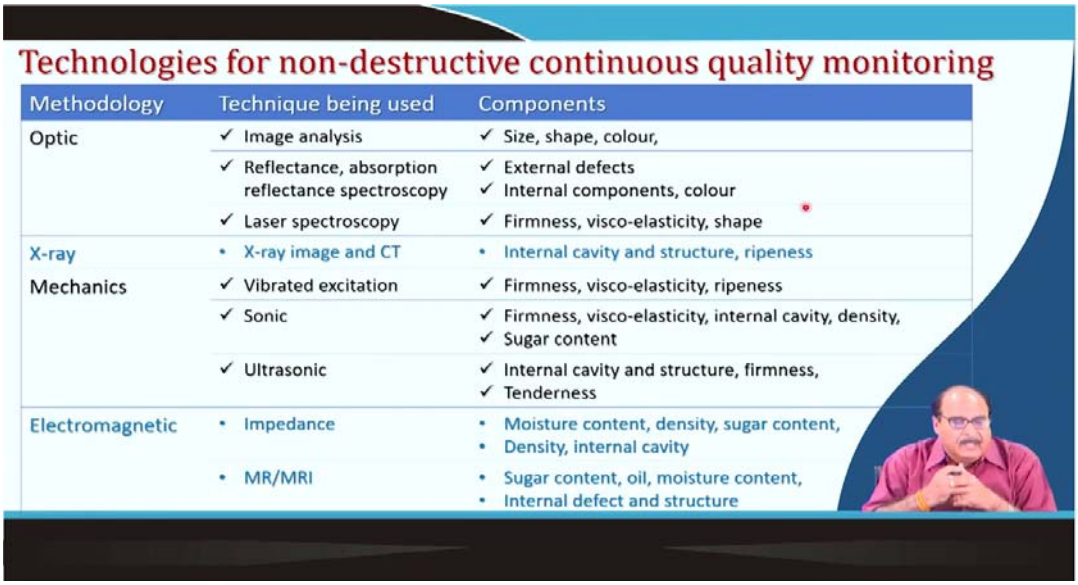
Manual evaluation of texture can be done by mechanical texture analysis or evaluation of absence of different defects or deterioration of color. External quality parameter can also be measured by mechanical methods like ultrasound.

Internal quality like order, taste, and texture can be qualitative or subjective methods. These include sensory methods as well as instrumental methods. Instrumental methods are like gas chromatography, are becoming more popular nowadays than oral testing or sensory evaluation of sweetness, bitterness, sourness. Furthermore, technical quantification of the taste compounds using HPLC can be done. Texture profile like firmness, tenderness, mouthfeel can be measured by applying the force to the produce and analyzing that how much force is required to break or rupture the product.



Wholesomeness and nutritive value are food safety attributes which are considered as a ***hidden quality attributes*** they can be analyzed by laboratory methods and instrumental method for determining micronutrients and phytochemicals.

There are standard setup procedures and protocols which can be used to determine their antigenic microbial load content of chemical contaminants. The presence of foreign matters should be analyzed.



Technologies for non-destructive continuous quality monitoring

There are some non-destructive methods for continuous quality monitoring for fruits and vegetable. These methods include optic, X-ray mechanical method and electromagnetic method.

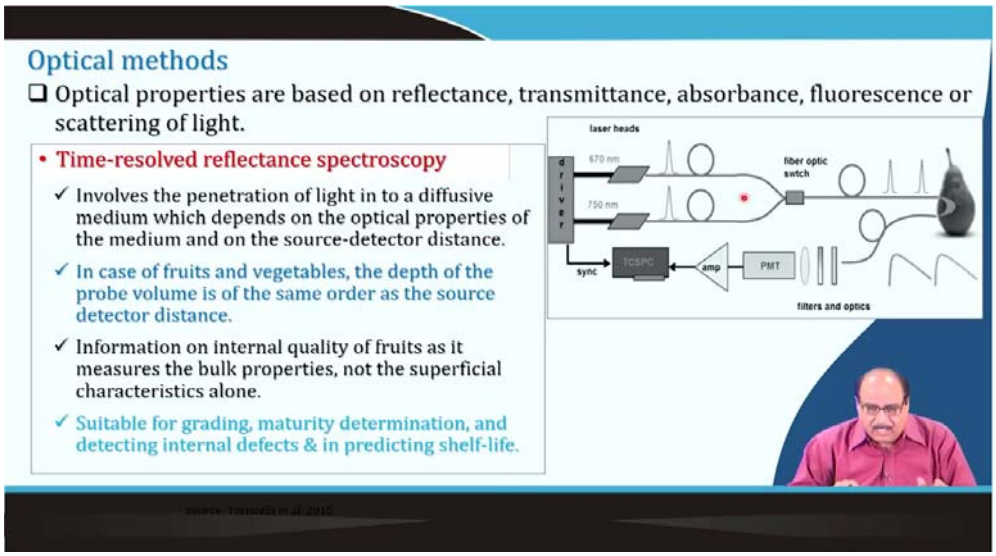
1. ***Optic method***: Determination of the size, shape, color, reflectance and absorption can be achieved by Image analysis. It can be also be used to find out if there is any external defect in the commodity.

   Similarly, ***reflectance spectroscopy*** can be used for internal component analysis and color. ***Laser spectroscopy*** can be used to find out firmness and visco-elasticity for various commodities.

2. ***X-ray mechanics: X-ray image and CT:*** can be used to find out internal cavity and structure, and degree of ripeness of the produce so that the material is fully ripe or less ripe can be found out.

   In the ***mechanical methods***, vibrated excitations can be used to find firmness, visco-elasticity, ripeness. ***Sonic method and ultrasonic*** method can be used again to find firmness, visco-elasticity as well as the internal cavity, density, sugar content, and tenderness.

3. ***Electromagnetic methods*:** These are used to find impedance which is used to determine moisture content, density, sugar content and internal cavity. Similarly, MRI can be used to find out sugar content, oil content, moisture content or internal defect and internal structure of the material.

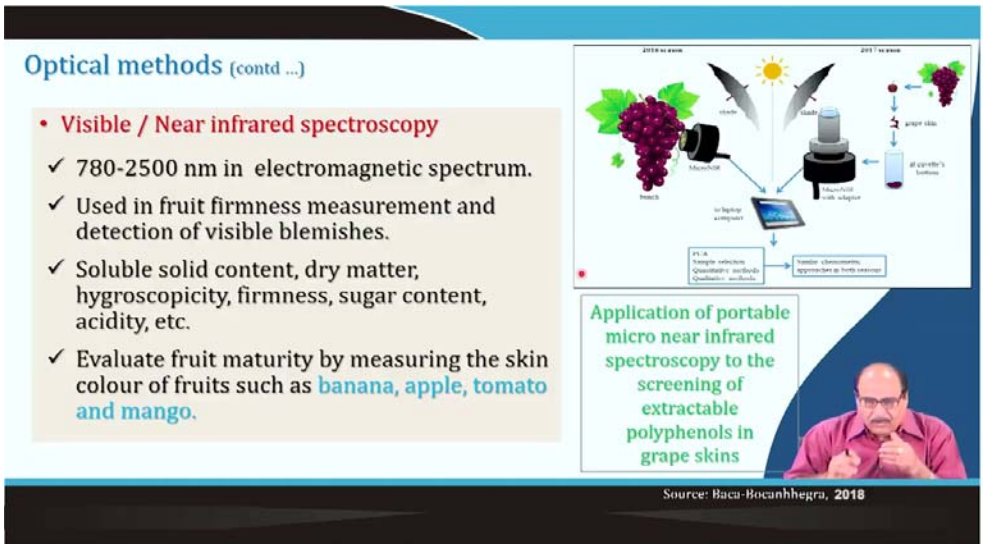


Optical methods

These optical properties are based on reflectance, transmittance, absorbance, or fluorescence or even a scattering of light. So, any of these properties can be used to determine the optical characteristics.

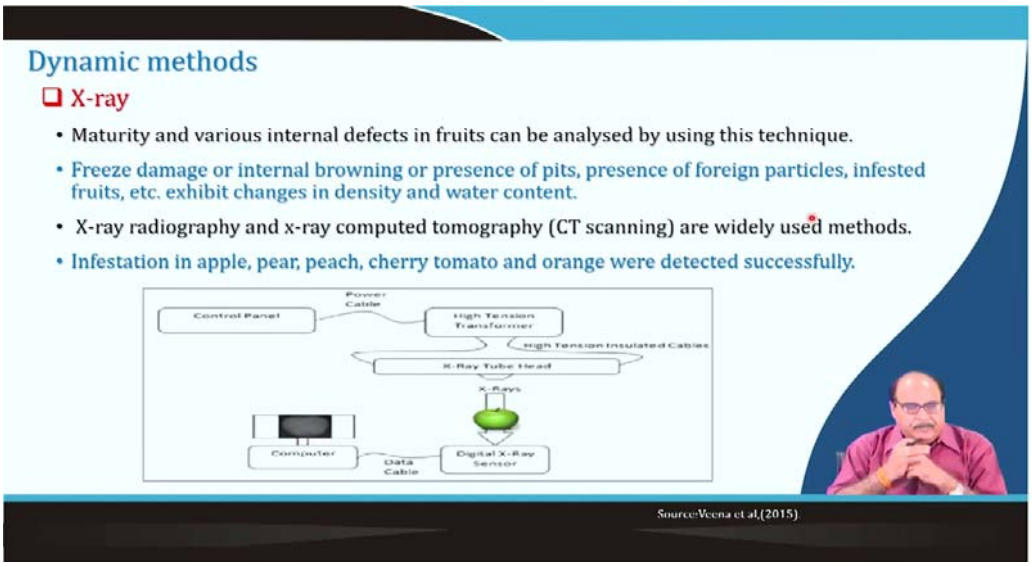
Time-resolve reflectance spectroscopy is a simple setup page which involves the penetration of light into a diffusion medium which depends on the optical properties of the medium and under source detector distance.

In case of fruits and vegetable, the depth of the probe volume is of the same order as the source detector distance. It provides information on internal quality of fruit, as it measures the bulk properties not the superficial characteristics alone. As this method can give information about the internal quality characteristics, it is suitable for grading, maturity determination and detecting the internal defects and in predicting the shelf life of fruits and vegetables.



Visible or near infrared spectroscopy includes wavelength ranges from 780 to 25,000 nm in electromagnetic spectrum. It can be used for analyzing various properties such as fruit firmness measurement and detection of visible blemishes, soluble acid content, dry matter, hygroscopicity, firmness, sugar content, acidity etc. Fruit maturity of banana, apple, tomato, and mango can be determined by evaluating the skin color by using visible or NIR spectroscopy.

The application of portable micro near infrared spectroscopy to the screening of extractable polyphenols in the grape fruits is shown here in this figure. This set constitutes a spectroscopic camera, monitor, a micro NIR and an adaptor. The subject (grapes) information this is sent to the micro NIR with an adapter and micro NIR which reads the spectra and send the information to the laptop or computer where the required data is analyzed by various quantitative method or qualitative method like PCA,. There is some software which analyzes the spectra and give the output as well.

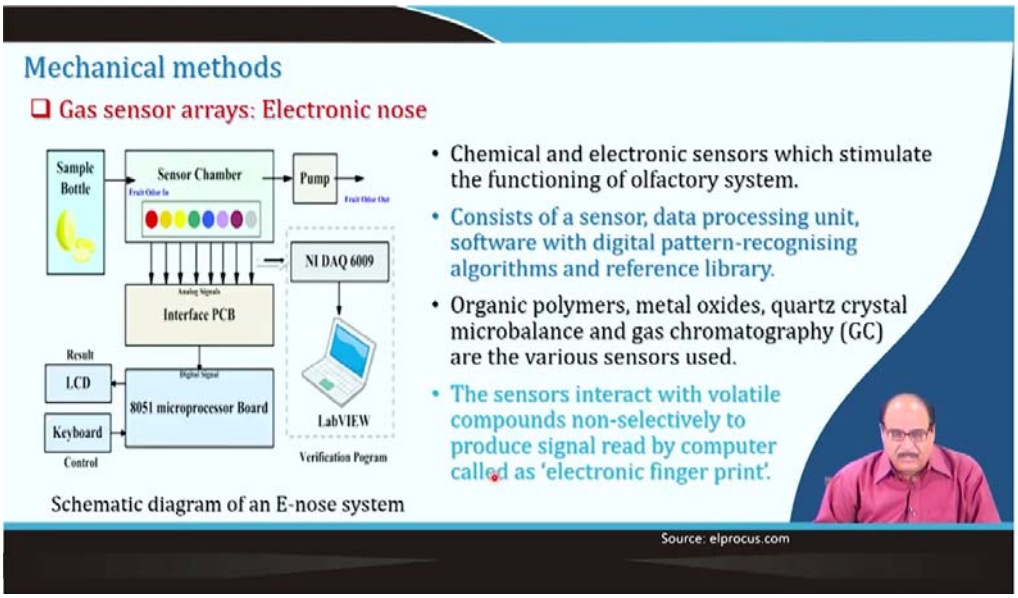


Dynamic method

X-ray imaging which is a dynamic method, can detect maturity and various internal defects. For example, freeze damaged or internal browning or presence of pits, presence of foreign particles, infestation which exhibit changes in the density and the water content.

X-ray radiography and the X-ray computed tomography (CT scanning) are widely used method. Infestation in apple, peach, pears, cherry, tomato and orange have been detected successfully using this X-ray imaging.

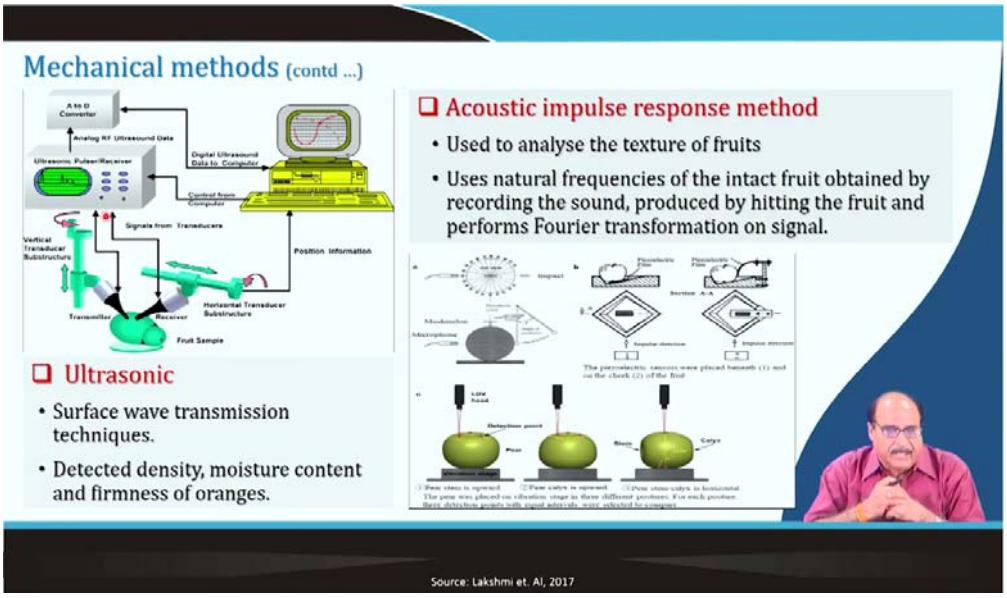
In the given figure there is a computer, a control panel along with high tension transformers and high tensile insulated cables connected to the X-ray tube head to X-ray sensor. The sensor absorbs the data and pass it on to the computer, where it is analyzed using appropriate software and the output is given.



Mechanical method

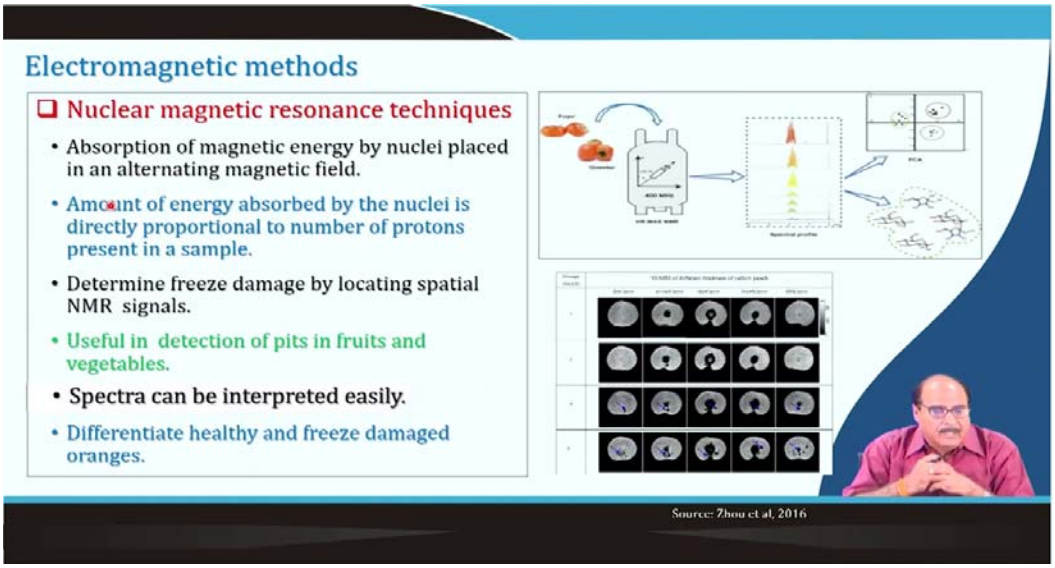
Then mechanical method includes ***gas sensor array or electronic nose***. Chemical and electronic sensors are there in the electronic nose which is simulate the functioning of olfactory system

Electronic nose has various sensors that constitute data processing unit software and digital pattern recognizing algorithm and a reference library. When a sample is given and the volatile components which are present in the sample which are responsible for the flavor: evaporates and these volatile components are sent to the gc chamber. The sensor interact with the volatile compounds non selectively to produce signal and this signal is read by the computer which is called as "electronic finger print" and then these signals are analysed for determination of quality attributes.



The ***acoustic impulse response method*** is used to analyze the texture of fruits. It uses natural frequencies of the intact fruit which is obtained by recording the sound, that is produced by hitting the fruit and then by Fourier transformation the signal is analyzed.

Similarly, ***ultrasonic*** *i*s a surface wave transmission technique. It is used to detect the density, moisture content and firmness of many commodities. In the case of oranges, it had been successfully applied to determine quality attributes.

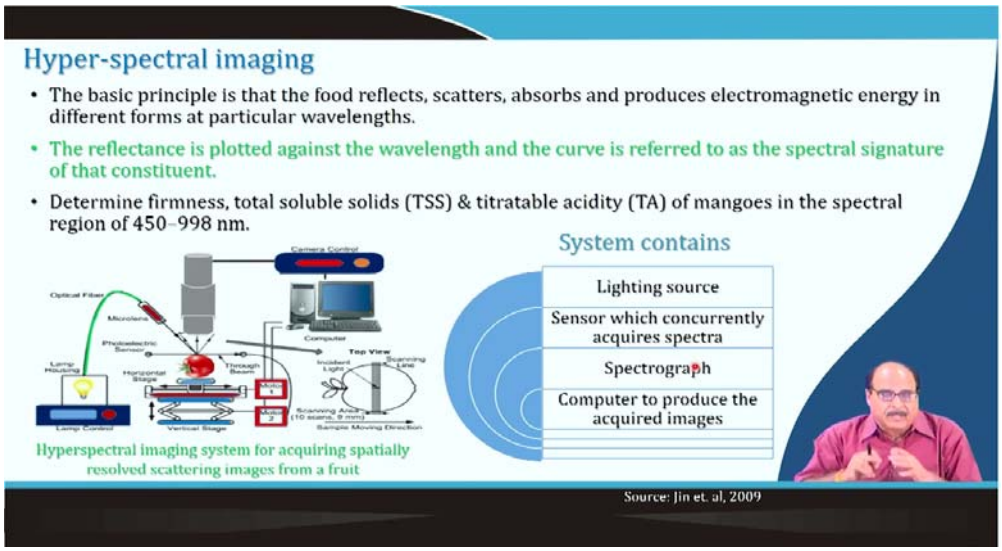


Electromagnetic method

Electromagnetic method which includes ***nuclear magnetic resonance techniques*** is a absorption of magnetic energy by nuclei placed in an alternating magnetic field. The amount of energy absorbed by the nuclei is directly proportional to the number of protons present in a sample. It determines the freeze damage by locating the special NMR signals and also useful in detection of pits in fruits and vegetables. Spectra can be interpreted easily and can differentiate into healthy and freeze damaged oranges.

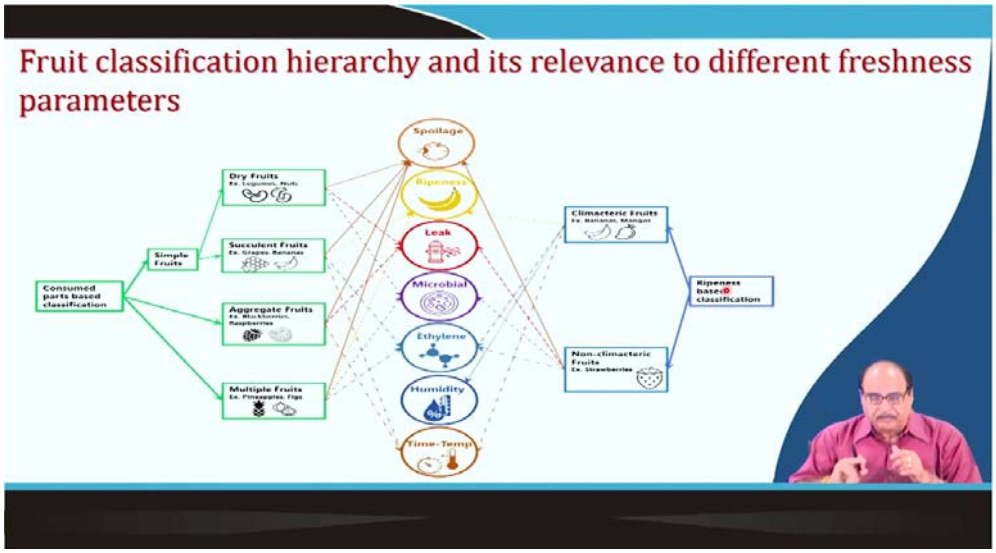
The ***machine vision*** system usually consists of five basic components i.e light source, an imaging unit, an image capture board, computer hardware and software. An automatic machine vision system was industrialized to detect small insects raspberry fruit.

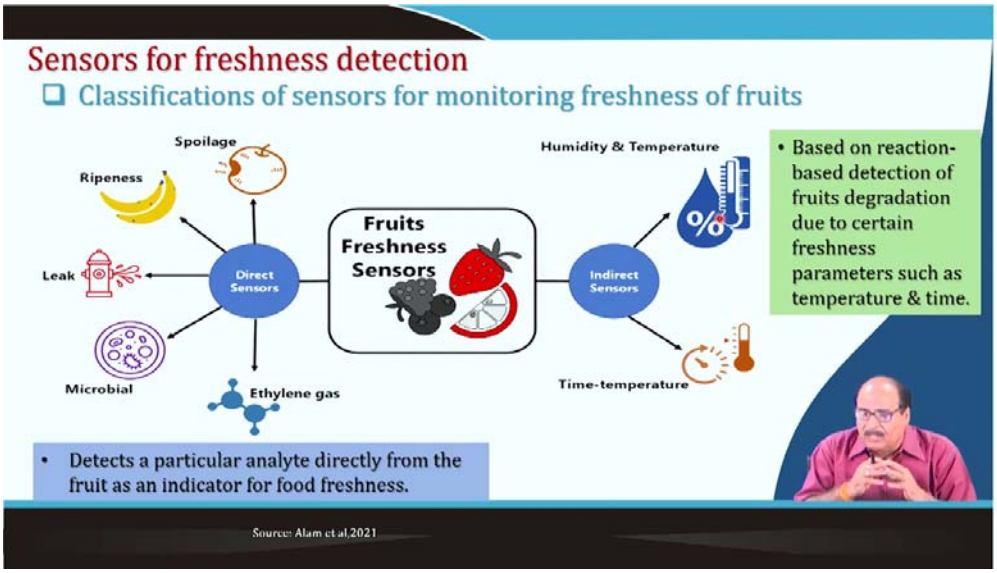
The given figure represents a machine vision system where the commodity (tomato) is placed in front of the light source. The light sources determine the light and are sensed by the camera. The camera sends the signals to the computer CPU where it monitors and analyzes. The image and result is displayed on the monitor.



Hyperspectral imaging

The basic principle of ***hyperspectral imaging*** is that the food reflects scatters, absorbs and produces electromagnetic energy in different forms at particular wavelength. The reflectance is plotted against the wavelength and curve is referred to as the spectral signature of the constituent. It helps in determining the firmness, total soluble solids (TSS), titratable acidity (TA) of mangos in the spectral regions are 450 to 998 nm. The hyperspectral imaging system contains lighting source sensor which accurately acquires a spectra, spectro graph or computer to produce the acquired images.



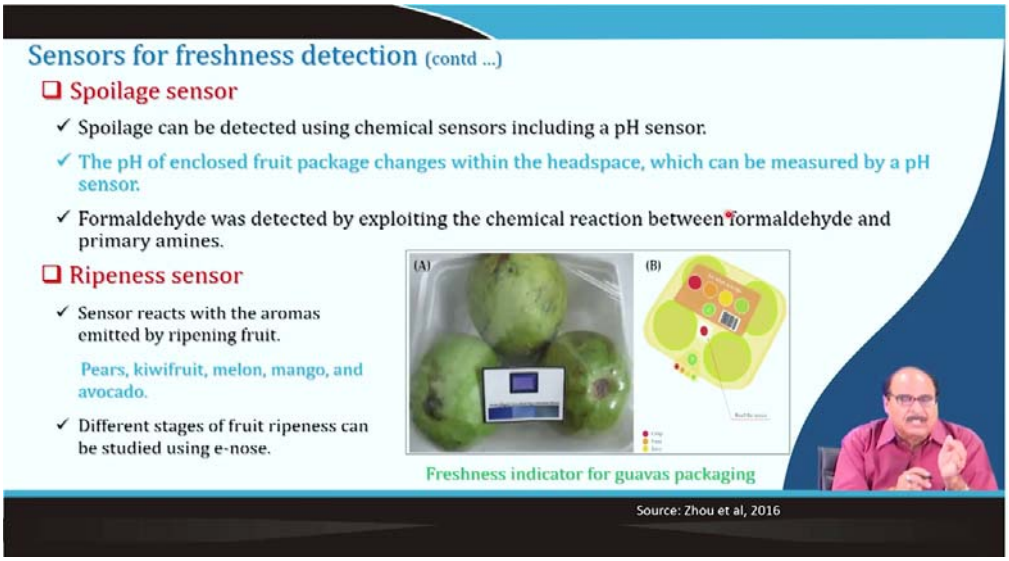


Different freshness parameter

For climatic fruits parameters like ethylene production, humidity and temperature, time maintenance inside the storage environment that may be taken as criteria for the quality determination. Similarly, for dry fruits, spoilage or leak or the microbial contamination can be considered. In the case of multiple fruits that ethylene and microbial contamination or spoilage can be taken as the indicator for freshness. The freshness indicators helps to determine whether the material is good for consumption or has been spoiled.

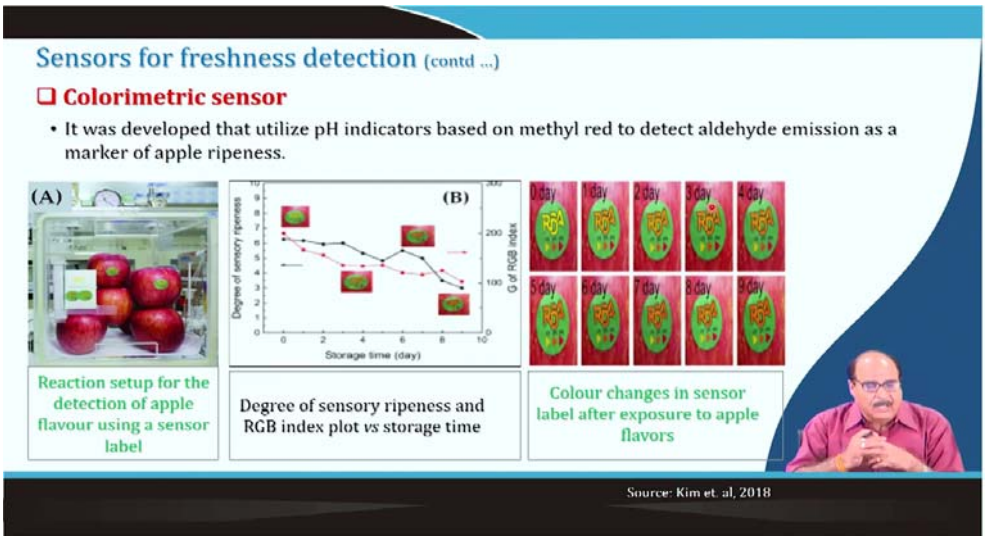
Sensors for freshness detection

Direct sensors can detect spoilage, ripeness, leak, microbial contamination and ethylene gas production. On the other hand, ***indirect methods*** detect humidity and temperature. The direct methods detects a particular compound directly from the fruit as an indicator of the food freshness and the indirect methods are good and the based on the reaction based detection of degradation due to certain freshness parameters such as temperature and time.

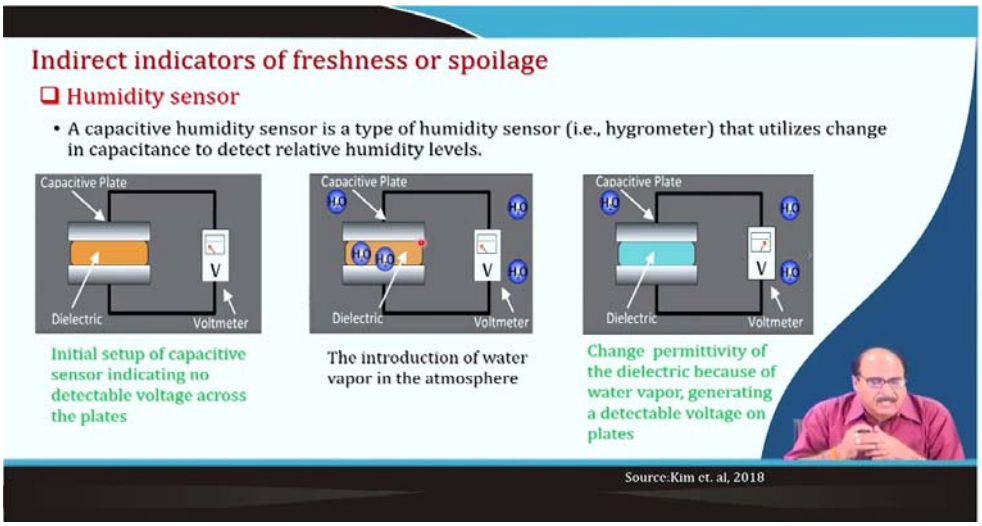


In case of ***spoilage sensor***, the spoilage can be detected using chemical sensor including pH sensor. The pH of the enclosed fruit package changes within the headspace, which can be measured by using a pH sensor. Formaldehyde can be detected by exploiting the chemical reaction between the formaldehyde and the primary amines.

Then similarly, ***ripeness sensor*** reacts with the aroma emitted by the ripened fruits like Pears, Kiwi, Melon, Mango etc. And different stages of fruit ripeness can be studied using even e-nose.

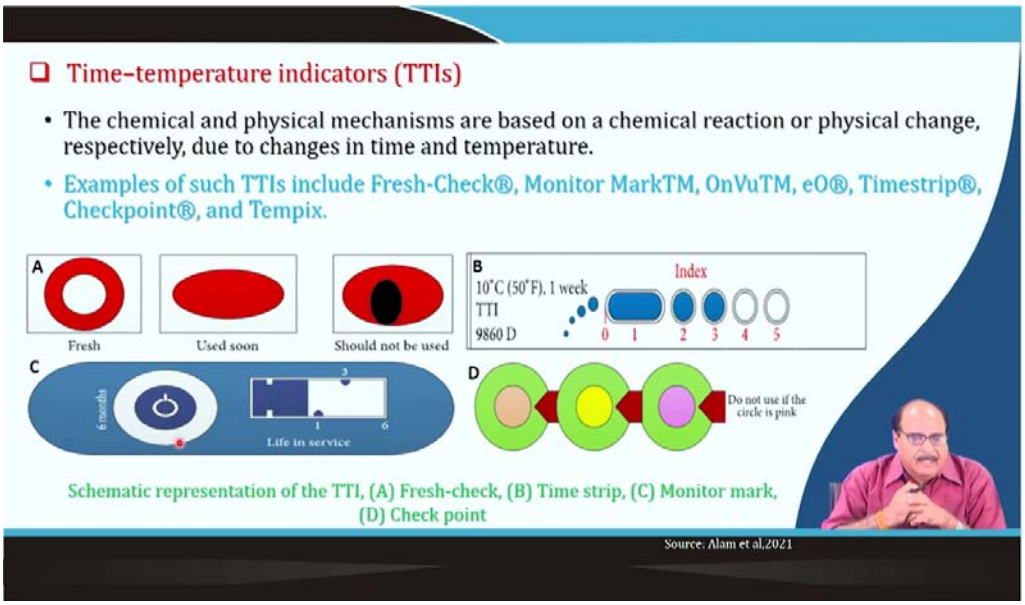


Colorimetric sensor utilizes the pH indicator based on methyl red to detect aldehyde emission as a marker of the apple ripeness and this can be used for similar such other fruits. In this figure, the Degree of sensory ripeness and RGB index plot vs storage time relationship is shown. There is a Colour changes in sensor label after exposure to apple flavors and on the basis of these color changes, one can get an idea about its freshness.



Indirect indicators of freshness or spoilage

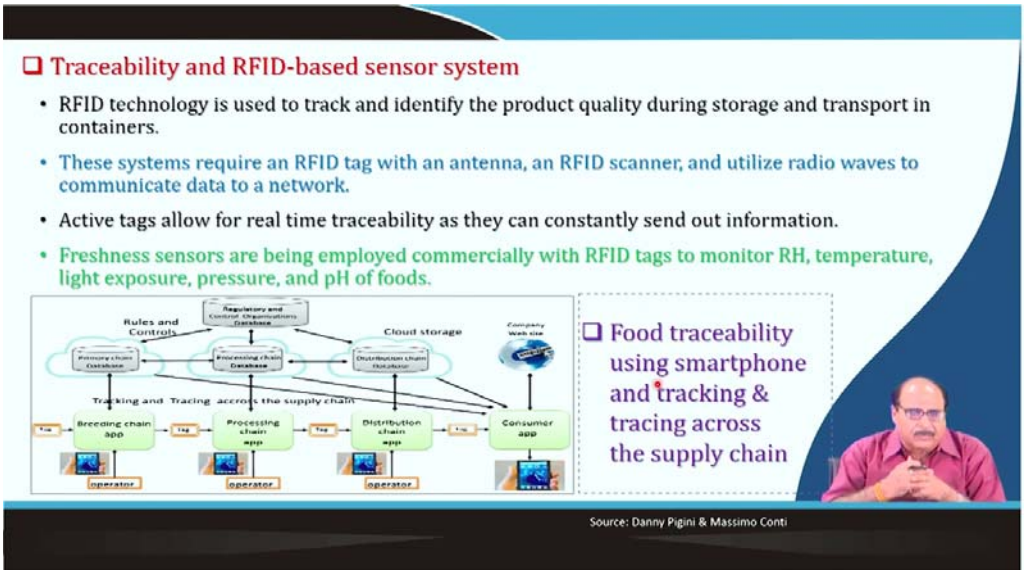
Similarly, the indirect sensors like the capacitive ***humidity sensor*** are a type of humidity sensor (i.e., hygrometer) that utilizes change in capacitance to detect relative humidity levels. The first figure is indicating the initial setup of capacitive sensor indicating no detectable voltage across the plates and then the introduction of water vapor in the atmosphere is shown in the second figure. The change of permittivity of the dielectric because of the water vapor generating a detectable voltage on the plates is displayed in the third figure and that is measured by this sensor.



Time temperature indicator

Time temperature indicator empowers on chemical and physical mechanisms that are based on a chemical reaction or a physical change respectively due to changes in the time and temperature. There are various TTI indicators available in the market which include Fresh-Check®, Monitor MarkTM, OnVuTM, eO®, Timestrip®, Checkpoint®, and Tempix.

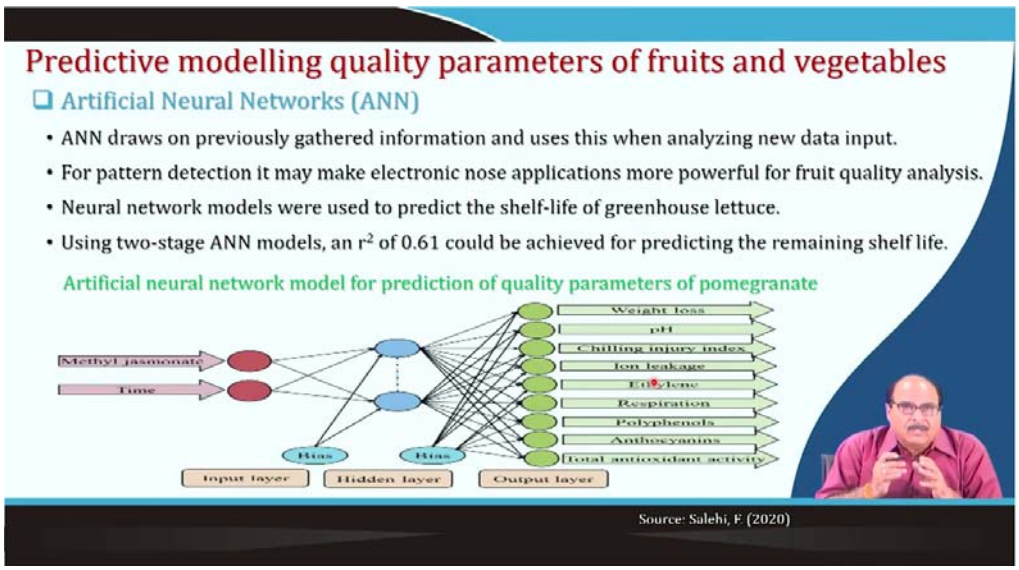
In monitor mark figure C the ethyl label is completely blocked indicating the freshness. In figure D, if the circle is pink, it indicates spoilage. So, there are various combinations of TTIs by using nano technology and the sensors that are produced can give the desired information.



Traceability and RFID based sensor

The traceability and RFID based sensor system indicator is used to track and identify the product quality during storage and transit. These systems require RFID tag with an antenna and an RFID scanner and utilize radio waves to communicate data to the network. These active tags allow the real time traceability as they can constantly send out information. Freshness sensors are being employed commercially with RFID tags to monitor relative humidity, temperature, light exposure, pressure, pH of foods or even during transit they are used to check whether the material is in good condition or not.

Food traceability using smartphone and tracking and tracing across the supply chain can be achieved by developing an mobile app and displaying the data from RFID on the app. So, this is how the smart apps and cloud storage is being used for traceability

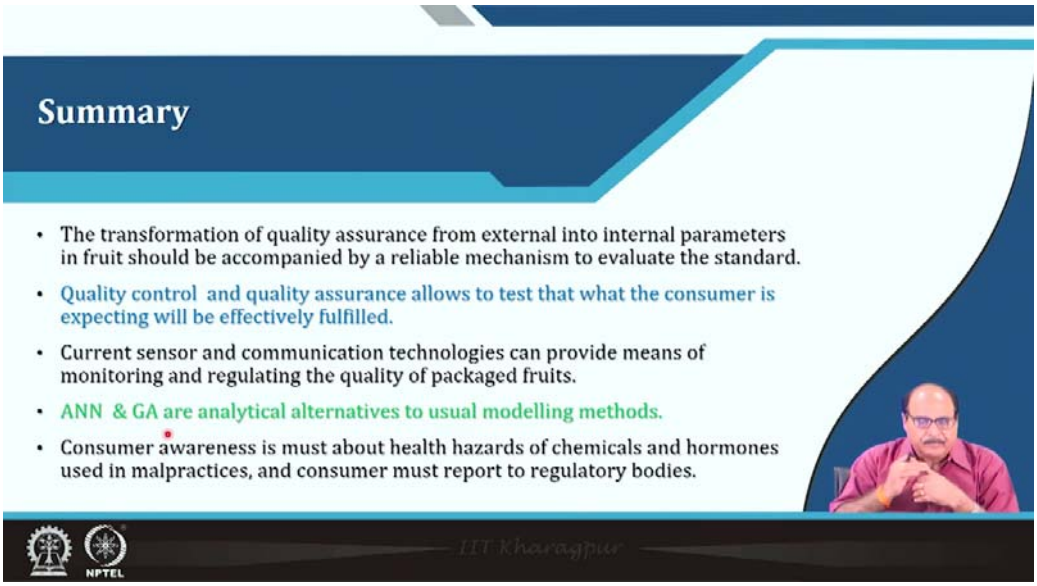


Predictive modeling of quality parameters of fruits and vegetables

Artificial neural network (ANN) is one such model which is mostly used for predictive modeling of quality parameters. ANN draws on previously gathered information and uses this information when analyzing new data point. So, for pattern detection, it may take the make the electronic nose applications more powerful for fruit quality analysis.

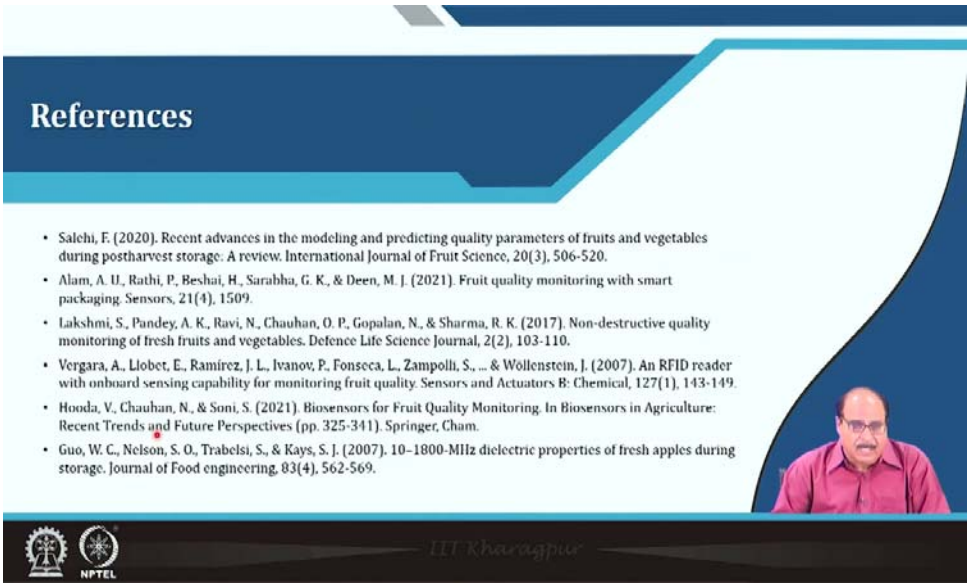
So, neural network models are used to predict the shelf life of greenhouse lettuce or any other any such their commodity. So, by using two stage ANN model system models were developed which could predict the shelf life of the fruit.

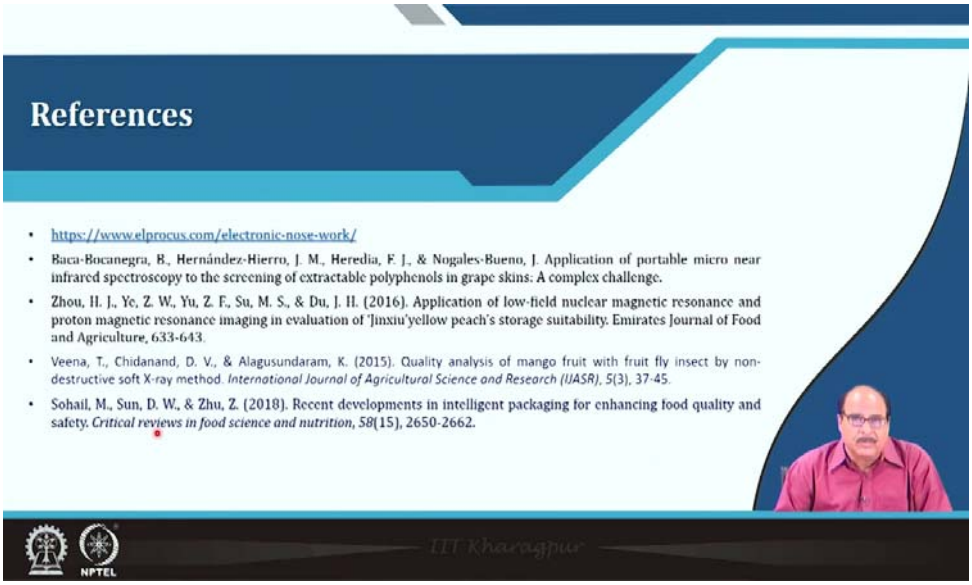
ANN model system consists of input, output and hidden layer. It could analyze the bais and send it to hidden layer and finally, on the basis of this analysis the model gives output which may be of any particular desired quality like weight loss, pH, calorie, ion exchange, ethylene and respiration etc.



In summary, transformation of quality assurance from external into internal parameters in fruits should be accomplished by a reliable mechanism to evaluate the standards. Quality control and quality assurance allows to test that what the consumer is expecting will be effectively fulfilled. Current sensor and communication technologies can provide means of monitoring and regulating the quality of the package fruits and vegetables. artificial neural network and genetic algorithm are analytical alternatives to visual modeling methods.

Consumer awareness is must about health hazards of chemical and hormones used in malpractices. The consumer must report this to the regulatory bodies about any malpractice in the value chain or if the commodity or material is not of desired quality and safety standards.





These are the references for further study. Thank you.