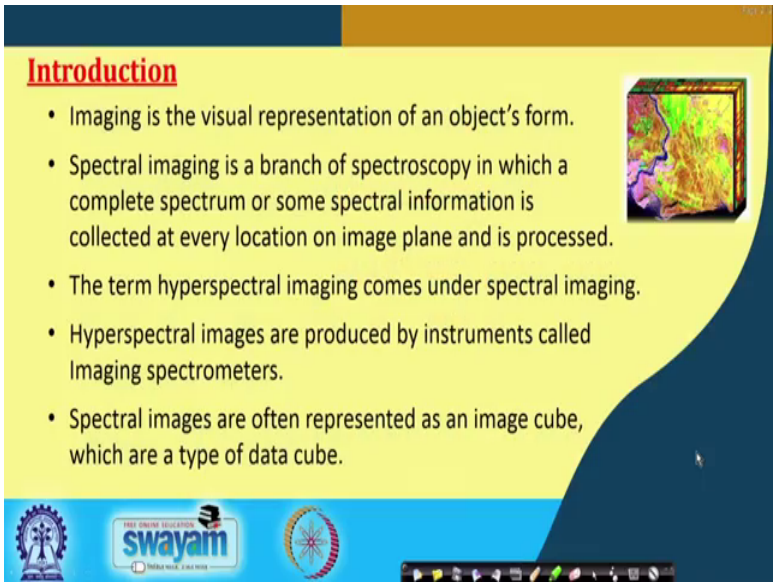
Novel Technologies for Food Processing and Shelf Life Extension

Prof. Hari Niwas Mishra
Department of Agricultural and Food Engineering
Indian Institute of Technology, Kharagpur

Lecture – 47
Food Quality Analysis Through Hyperspectral Imaging

Hello friends, now in this lecture we will study Food Quality Analysis Through Hyperspectral Imaging although this technology of hyper spectral imaging can be analyzed or can be used to analyze various quality attributes of different food materials. But in my this lecture, I will focus more towards its use on grain quality analysis particularly infestation etcetera in the grain and that we have done in our work our laboratory. But in fact I will also take up one or two examples of its use in the different food material like meat, fish, etcetera from the literature.

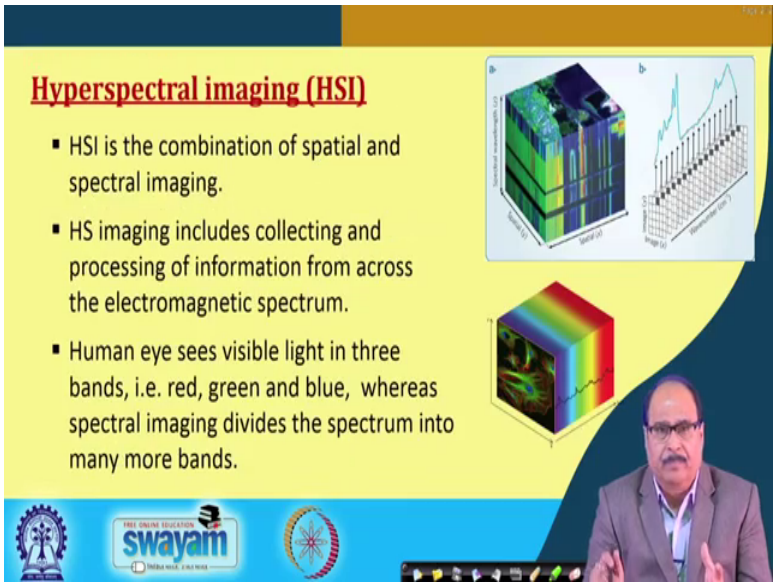
(Refer Slide Time: 01:15)



So, first let us see what this hyper spectral imaging is in fact before going to hyper spectral imaging. Let us see the imaging. What do we mean by imaging system, image are as in how image is formed. So, in fact, as you can see in this slide image is the visual representation of an objects form. A spectral imaging is a branch of a spectroscopy in which a complete spectrum or some a spectral information is collected at every location on image placed image plane, and it is the information thus collected spectral information is processed. The term hyper spectral imaging comes under the domain of a

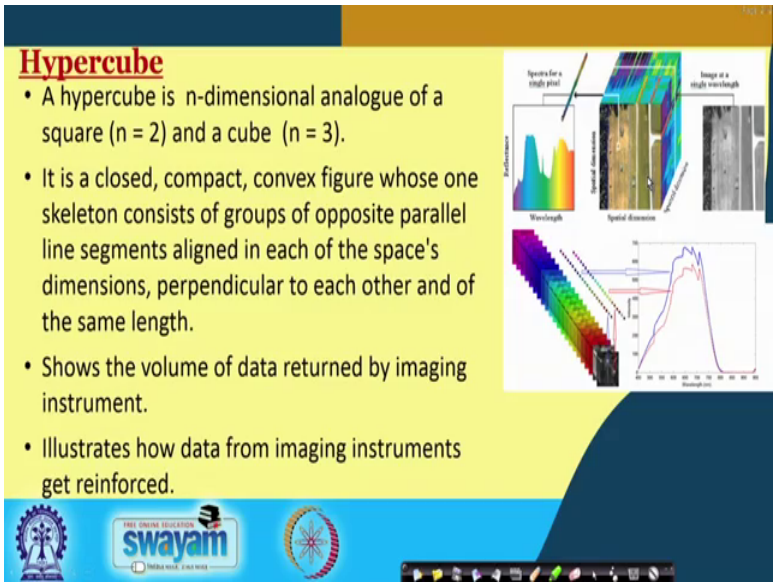
spectral imaging, hyper spectral images are produced by instruments called imaging spectrophotometers. Spectral images are often represented as an image cube which are a type of data cube.

(Refer Slide Time: 02:37)



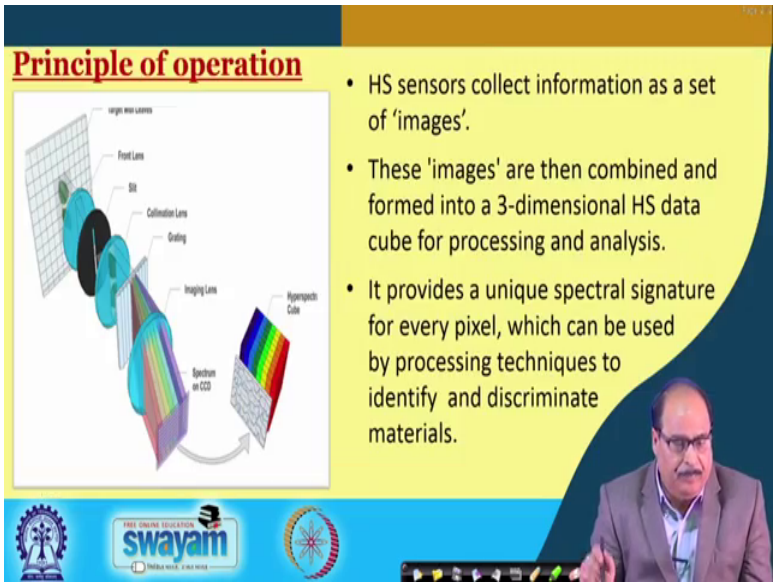
Here you can see in this slide that is the image cubes are shown in the pictures. So, hyper spectral imaging is the combination of a spatial and a spectral imaging. The hyper spectral imaging includes collecting and processing of information from across the electromagnetic spectrum of the material. In general the human eyes see visible light in three bands that is the red, green and blue. But here the hyper spectral imaging camera it divides the a spectrum into many more bands and these data generated in many more bands from different locations of the material at in different conditions, these are processed and finally represented into some sort of image.

(Refer Slide Time: 03:41)



And that is hypercube you could see in the earlier slide in the picture, here also in this slide you can see the hypercube is basically a n-dimensional analog of a surface. It may be a square that is where n is equal to 2, or it may be a cube that is n is equal to 3. So, it is hypercube is a n-dimensional analog of a square and cube. It is closed, compact, convex figure whose one skeleton consists of groups of opposite parallel line segments aligned in each of the space's dimensions which are perpendicular to each other and are of same length. So, this hypercube, you can see here in this picture it shows the volume of data returned by imaging instruments, and it illustrate how the data from the imaging instruments get reinforced to reproduce the image.

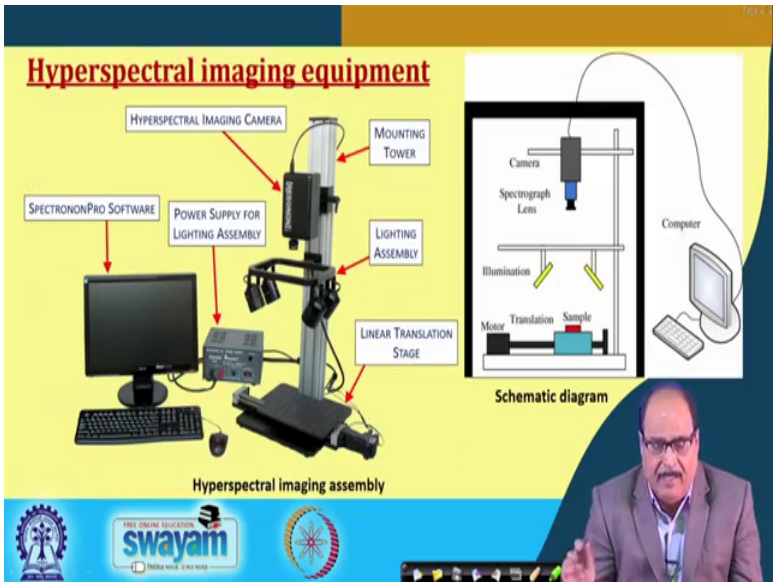
(Refer Slide Time: 04:56)



As far as the principle of operation of this hyper spectral imaging technology or hyper spectral imaging system concerns in the later part of this and maybe in other slide I will show you the different components of the different hyper imaging system, but it here there are some sensors. So, obviously, the sensors hyper spectral sensors collect information as a set of images. These images are then combined and formed into a three-dimensional hyper spectral data cube for processing and analysis. And it provides actually a unique a spectral signature for every pixel which can be used by processing techniques to identify and discriminate material.

So, here that is you can see there are the different lenses the image is acquired by the camera there is and then it is passed through different lenses and finally, this data collected is and signals collected etcetera, they are processed, and finally converted into hyper spectral cubes which are further analyzed.

(Refer Slide Time: 06:18)



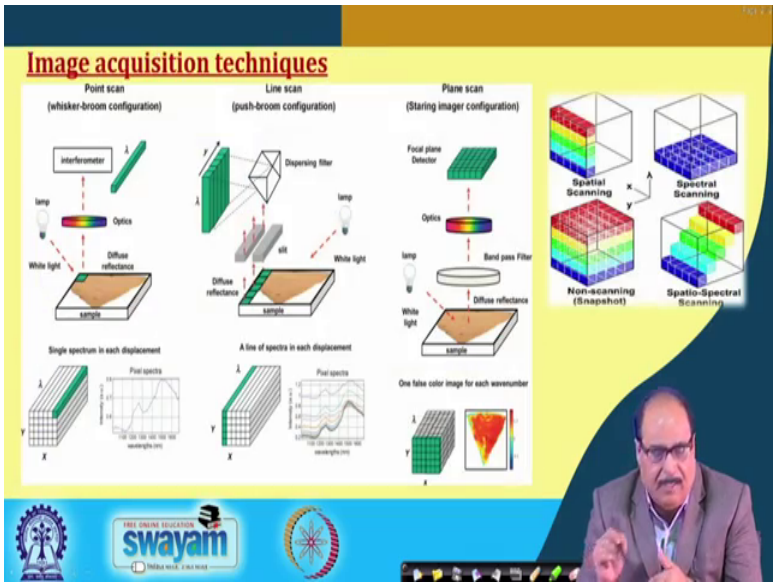
So, this the hyper spectral imaging equipment consists basically you can see here this is actual photograph of the hyper spectral imaging system which we have in our laboratory, so which has a schematic of this system is that it contains a camera that is the camera for taking the image which is right here, that is hyper spectral image in camera. And then some lighting assembly, lights are provided for illumination of the sample which is kept here.

So, this sample the camera takes the image, and it take the data, and then it is passed to the computer where that is the different particular software depending upon the type of the material to be analyzed and characteristics of the material in the to a later part of this lecture, I will tell you what are the different software available so that is used to analyze the data and compare the result. So, this is the principle of operation, how spectral imaging equipment works and what are the different components present in the HS equipment.

(Refer Slide Time: 07:30)

So, as you have seen in the earlier case that is the light source obviously I told you, it illuminates the sample. White light can be used for NIR, and visible data collection. And a specific wavelength can be selected by using appropriate filters which are provided there in the instrument. Imaging optics, collects sample reflectance and illumination wavelengths, and there are filters provided may be tunable filters etcetera allows only a specific wavelength corresponding to a particular image to be captured by the camera. And finally, imaging charge coupled device that is CCD so called, it records intensities of individual pixels for which wavelength is the there in the data collection range. So, this is how it collects data since the well and processes it.

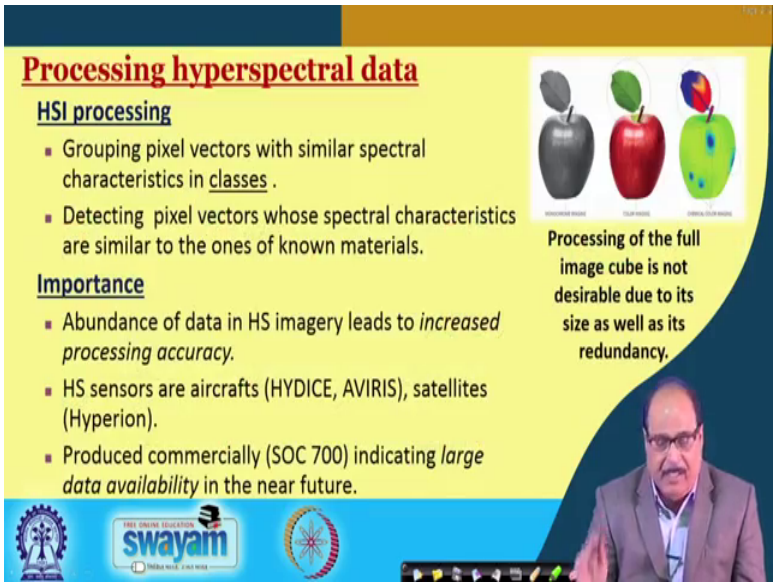
(Refer Slide Time: 08:34)



And this it is schematic representation of almost there that is there may be different types of image acquisition techniques like point scan, whisker broom configuration system there which use as a interferometer, the other case it is a line scan push broom configuration. There are dispersing filters and you can see there from the light source how the sample image is coming, and then data is sent to the dispersing filters, and finally it comes in the form of cubes.

And then in other case that is the even plane scan system it is as a staring imager configuration. So, this there are different image acquisition techniques depending upon what are the features a specific features available in the equipment available with you, one can use appropriate techniques for acquiring the image.

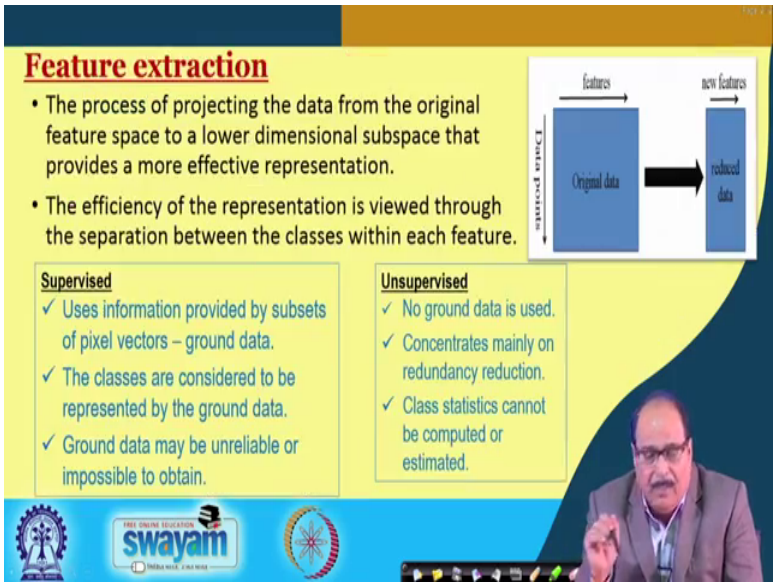
(Refer Slide Time: 09:30)



And finally is processing. So, once the image is acquired, our hyper spectral data, then it is processed, its processing means grouping these pixel vectors with similar a spectral collect characteristics in classes. So, that is when and then detecting pixel vectors whose spectral characteristics are similar to the one of known material. So, in that way, the data is grouped and finally, analyzed. So, this in fact, hyper spectral processing image processing data, it is very very important in nowadays.

It abundance of the data in hyper spectral imagery leads to increased processing accuracy hyper spectral sensors are used in aircrafts, satellites etcetera. And they are now produced commercially like SOC 700 which indicates that is these production indicates that large data availability are using that is the this technology in the near future, it has a good scope. So, it can be used for processing of the full image cube in that is the processing of the full image cube is not desirable due to its size as well as its redundancy as you can see here this picture.

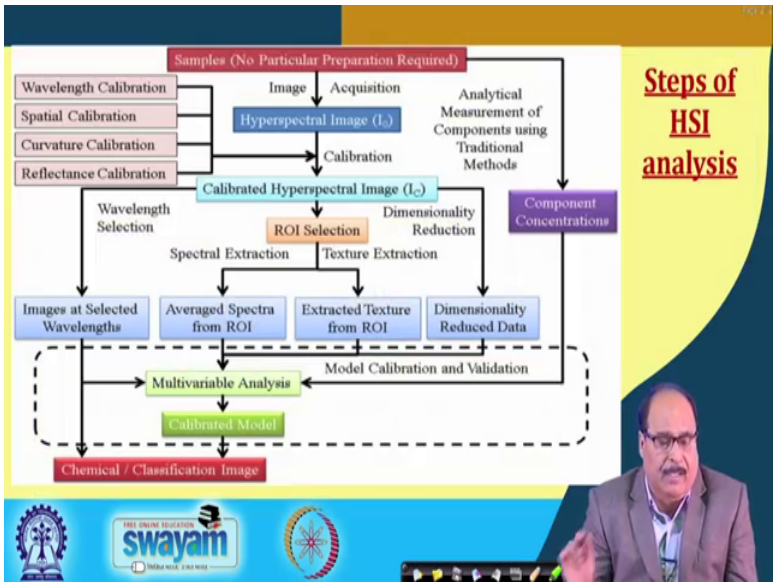
(Refer Slide Time: 11:04)



There is the feature extraction this process, this is the process of projecting the data from the original feature space to a lower dimension subspace that provides a more effective representation you can see that is the original data. So, the data points these features are sent to the new space which has a reduced that is the data reduce. The efficiency of the representation is viewed through the separation between the classes within each figure that is the pixels which have the similar characteristics they are grouped by the software.

They will be they were may be supervised feature extraction which uses information provided by subset of pixel vectors that is the ground data. And the classes are considered to be represented by the ground data. And ground data may be unreliable or impossible to obtain. In the case of unsupervised which had extraction, no ground data is used, concentrates mainly on the redundancy reduction, and class statistics cannot be computed or estimated.

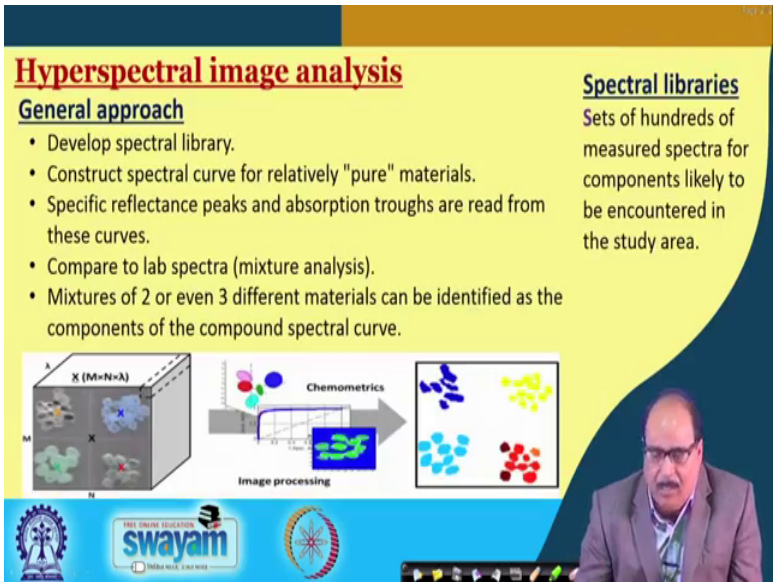
(Refer Slide Time: 12:25)



So, these are the steps of the HSI analysis that is hyper spectral image analysis that is the sample as it is can be used, there is no preparation of the samples etcetera is normally required. So, the sample it is kept on the sample image collecting platform, and then image is acquired by hyper spectral imaging camera, and then after the image is acquired, it need to be calibrated. And the calibration may be for the wavelength, for a spatial arrangement is spatial calibration, curvature calibration and reflectance calibration. So, system is to be calibrated or a particular wavelength a particular a spatial configuration in which image to be acquired all these things are adjusted in the equipment.

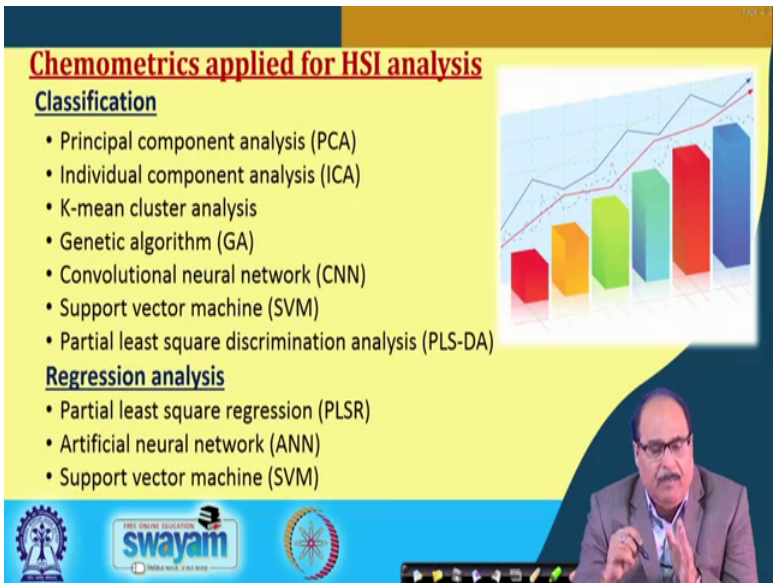
And then according to the calibrated hyper spectral image that is which is may be the wavelength selection image at a selected wavelength is obtained or dimensionality reduction that is are dimensionally reduced data are generated or ROI selection there is a spectral extraction or textural extraction that is averaged spectra from ROI are extracted texture from ROI these are generated. Finally, these all this data is sent to the computer for here using different softwares either by multivariate analysis etcetera is performed. And the calibrated model gives the different images are chemical images etcetera classified and grouped images adopted and which are finally compared with this known. So, that the how the hyper spectral images are analyzed by the software or by the computers.

(Refer Slide Time: 14:26)



So, the general approach for the analysis of the hyper spectral image that in this it develops a spectral library that is a spectral library are sets of hundreds of measured a spectra for components likely to be encountered in the study area. So, these spectral curves are constructed for relatively pure materials. A specific reflectance peaks and absorption drops are read from these curves. And then they are compared to the lab spectra that is by mixture analysis is done. And mixture of 2 or even 4 different materials can be identified as the components of the compound spectral curves.

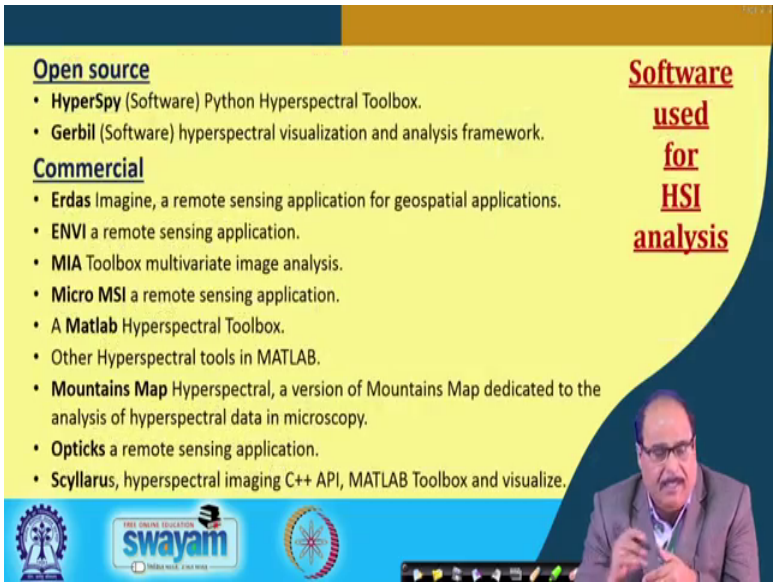
(Refer Slide Time: 15:26)



The chemometrics applied for HSI analysis like classification, grouping etcetera. The software different chemometrics are data analysis techniques are a blue like principal component analysis, individual component analysis, K-mean cluster analysis, genetic algorithm, support vector machines or partial least square discrimination analysis.

So, different methods, now one has to see that what is the most appropriate method to be used for the analysis of the image depending upon the requirements, and what is the type of the image, what is the image etcetera so accordingly. So, after this what is the even the some regression analysis like partial least square regression artificial neural network or support vector machine system etcetera can be used for analyzing the data.

(Refer Slide Time: 16:29)



Different softwares which are available or which are used for hyper spectral image analysis that is open source software include hyper spy are there will software that is which is used for hyper spectral visualization and analysis purposes. Then some commercial software that is Erdas, ENVI, MIA, micro MSI, MATLAB hyper spectral toolbox, other hyper spectral tools in MATLABs are also available. Mountains map hyper spectral which is a version of mountains map dedicated to the analysis of hyper spectral data in microscopy optics, scyllarus all these are the softwares that is the commercial software available which can be used for the processing or analysis of the data.

(Refer Slide Time: 17:29)

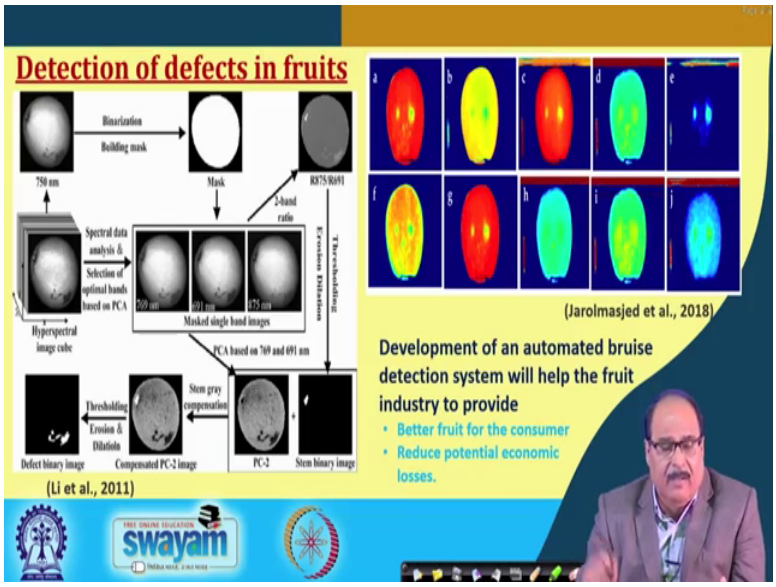
So, as far as the application of the hyper spectral imaging in food processing is concerned, it can be applied in various sectors like it can be used for analysis of the food quality like finding foreign matters such as plastic pieces, insects, etcetera in the food materials and then products. It can be analyzed for it can be used for analyzing particular quality or particular component of the food like concentration of sugar, homogeneity of different mixtures, or it can be used for controlling different production stages like the material characteristics before baking or after making or after mixing of the different. So, and all this thing that is the images can of the materials can be taken at various stages, and then the data can be analyzed to access the quality of the particular material at the particular stage.

Similarly, in the food packaging industry, this HSI can be used for ensuring or for analyzing the seal or for inspecting the seal or whether this packet is contaminated etcetera are the product uniformity, there is a quality assurance through packaging material that is packaging material whether it is inspect etcetera, even hyper spectral imaging camera etcetera is can be used for judging the cleaning efficiency and the equipments and so on.

It can be used it has a good application or potential application in use of the food sorting are for in developing, automated food sorting machine food sorting or grading systems like grains, seeds, dried fruits, etcetera, that is immature grains, infested grains are

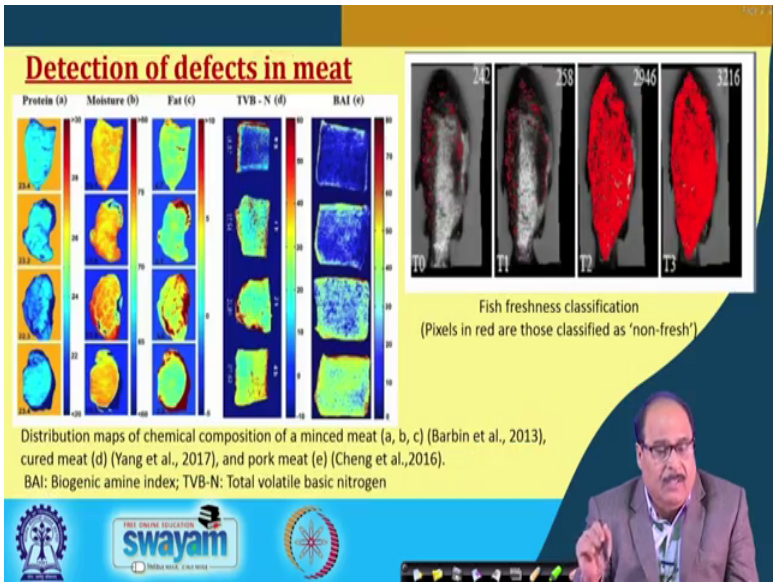
different sizes fruits etcetera or if the fruit is some it has got some damage, bruise, etcetera, all those things they can be sorted or graded using this hyper spectral imaging technology where fruit, vegetable, meats, grains, they are.

(Refer Slide Time: 19:43)



So, this is in fact as various researchers they have worked all right like Li et al, in 2011, they have reported a system for the detection of defects in food that is the using hyper spectral imaging techniques. They have detected the different image that is a even in Jarolmasjed et al, also they have reported article on the basis of the images taken of the different fruits and different conditions. They have analyzed that is whether if there any defect in a particular fruit. So, development of this an automated bruise detection system will help the food industry to provide better fruit for the consumers, and also to reduce potential economic losses because otherwise if that spoiled food is sent to the industry it may result into the loss.

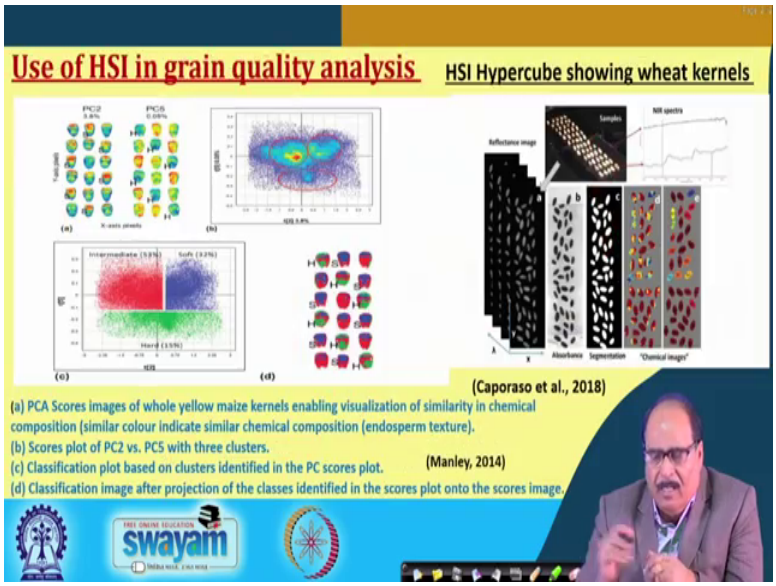
(Refer Slide Time: 20:49)



Similarly, that some researchers they have used this technology for detection of defects in meat. You can see here in this picture this side that is a Barbin et al, in 2013 they have by taking images of the different meats like in the minced meat, then cured meat. Yang et al, 2017 and pork meat, that is Cheng et al, 2016 they have indicated that is the protein content, the images, moisture, fat and this biogenic amine index or total volatile basic nitrogen index.

So, they have analyzed these components in the different meat samples through they have taken the image. And with the image of this pixels etcetera, they have grouped, they are classified that which one is a spoiled and is a like here in another study some researchers they indicated that fish freshness that the classification of the fish are their freshness. So, the pixels in the red are considered that is those are not fresh. So, more red image means that pixel fish is not fresh. So, this has the potential effect.

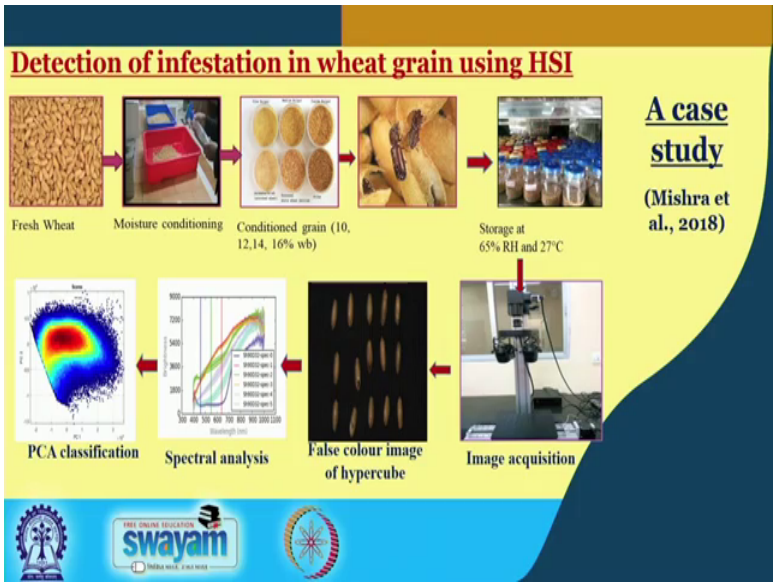
(Refer Slide Time: 22:11)



Similarly, that is a use of hyper spectral imaging in grain quality analysis some researchers have reported. It this is the hyper spectral imaging cubes showing wheat kernels. You can see here different images have different wheat kernels right. And this is a data given reported by Caporaso et al, in 2018. Then Manley et al, in 2014, they detected the quality of yellow maize kernels right that is the in picture a it is the PCA score images of whole yellow maize kernels enabling visualization of similarity in chemical composition that is the similar color indicate similar composition of the endosperm texture.

This in second picture b, it is the a score plot of PC 2 versus PC 5 with three clusters you can see clearly. The here picture c it is the classification plot based on cluster identified in PC score plot. And finally, that d the classification image after projection of the classes identified in the score plot and to the score images. So, in this way that is the quality grain quality analysis etcetera.

(Refer Slide Time: 23:51)

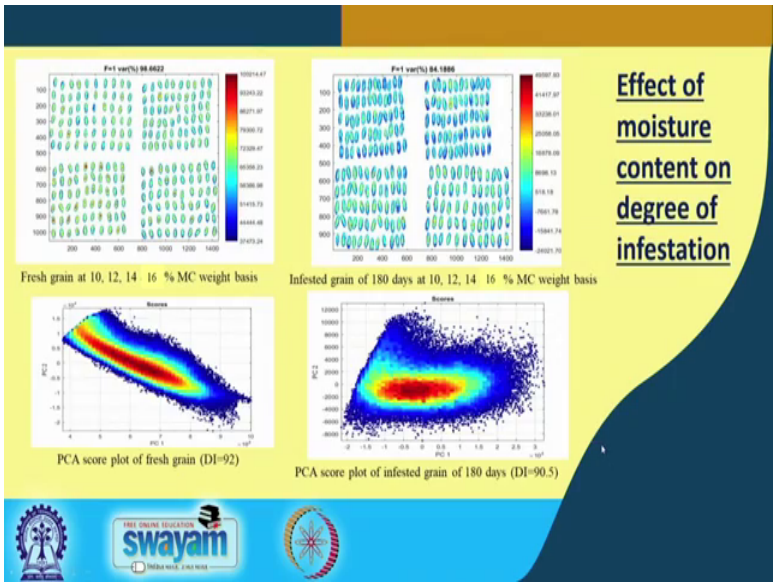


In our laboratory that is a Mishra et al, 2018 we have published this result also. We have as I told you we have conducted that is the we have detected infestation level, we have conducted experiment to find out the level of infestation in stored wheat grain. So, here what we have taken wheat fresh wheat sample, and it was a condition to different to moisture level by adding calculated amount of water to make the moisture content in grain to 10, 12, 14, and 16 percentage weight basis.

And these grains where allow a inoculated with known number of insects of different life stages of insect, and these were stored at 65 percent relatability and 27 degree Celsius temperature means that is all this exercise was done to get the infested wheat samples that is the wheat sample which have that is a known level or quantum of infestations. So, in the second once, we had the infested wheat sample and various combinations and permutations have been done.

So, wheat samples having different level of infestations having a containing different infestation stages of the insect etcetera, they were used. Now, they were images of these samples were acquired using hyper spectral imaging camera that we have in our laboratory. You can see here these are the false color image of the hypercube of the infested grain and then with the help of the chemo metrics software, these spectra as we are spectral were analyzed and finally the different principal cluster analysis was done this.

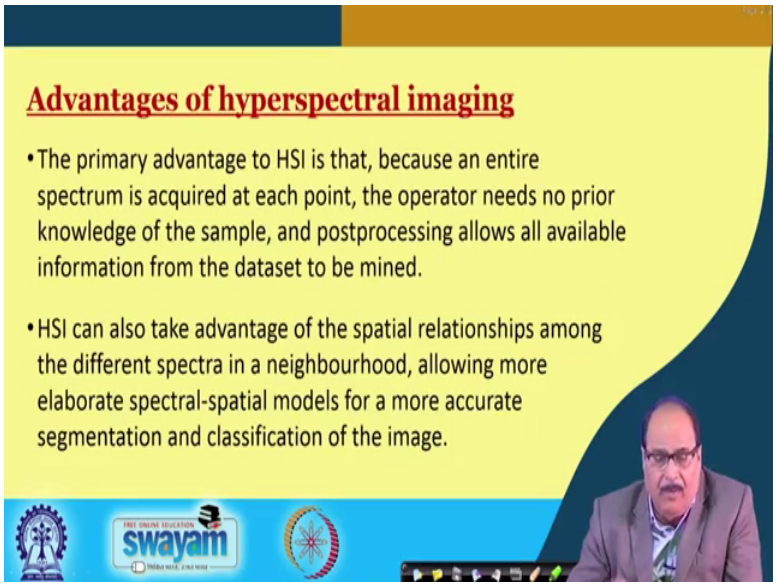
(Refer Slide Time: 26:06)



So, this you can see the imager that is effect of moisture content, and the degree of infestation which is our report in fact the these are the images of the fresh grain at 10, 12, 14 and this 16 moisture content, there is an weight basis. So, you can see that images now the infested grain. So, you can note clearly visible that is the difference between the fresh grain of 10 percent moisture content. And you can see the image of the infested grain of that is after 180 days that is at 10 percent moisture content.

So, it in all the cases of the 10, 12, 14, and 16 percent moisture content the by image one can clearly that is it is visible. And these two pictures in the bottom they so the PCA score plot of the fresh grain cause a principal component in the same plot. And this PCA score plot of the infested grain I had 180 days of storage. So, there are clear cut differentiation one can very clearly see that, yes, by observing by comparing the spectra of the fresh image as well as the infested the level of infestation and quantum of infestation can be analyzed can be found out.

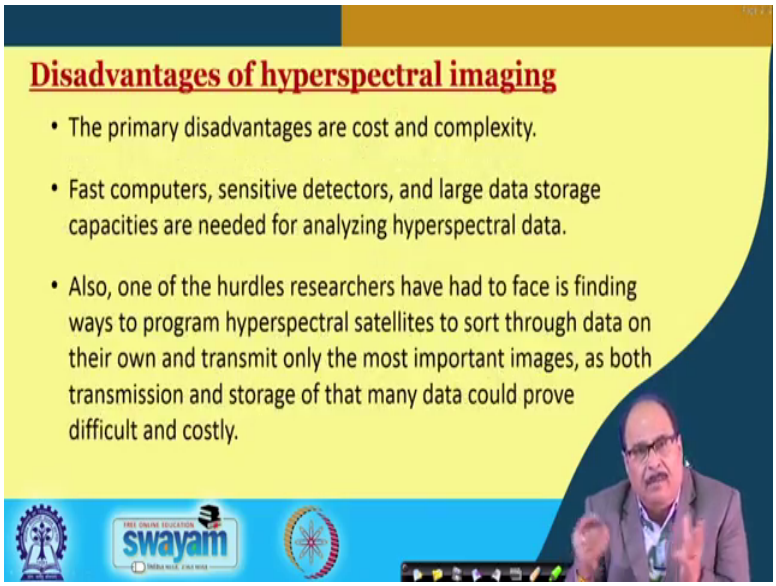
(Refer Slide Time: 27:32)



So, this hyper spectral imaging technology, it is a has a vast potential for application in food processing industries it has many advantages. The primary advantage that because an entire a spectrum is acquired at each point. The operator needs no prior knowledge of the sample, even a person who does not have the technical knowledge of the sample can do this, can take the image, they analyze the data, and the post processing allows all available information from the data set to be mined.

Hyper spectral imaging can also take advantage of the a spatial relationships among the different spectra in a neighborhood, allowing more elaborate a spectral-spatial models for a more accurate segmentation and classification of the image.

(Refer Slide Time: 28:51)



However, now it is a advantageous technology, very good technology, but at the same time like every other methods here hyper spectral imaging process also had has certain drawbacks like number 1 the most important it is a costly process and it is little bit complex particularly, these analysis of the data image taken anyone can take the image. But to analyze the image to process the image use of the appropriate software all these things needs some skill, technical competence, the computers very fast computers even very sensitive detectors and large data storage capacities are needed for analyzing the images or hyper spectral data.

And also, one of the hurdles researchers have had to face is finding ways to program hyper spectral satellites to sort through data on their own and transmit only the most important images, as both transmission and storage of the data may that many data could prove difficult and costly. So, if such systems are available, some analysis etcetera is available which can sort or that is take only the required images their required data and if that is transmitted a system is able to transmit that only required etcetera, etcetera that may be a good thing. So, where is in these are the some of the drawbacks for up this technology.

But let me tell you that this hyper spectral imaging technology it is emerging area in food processing, food quality analysis, and it has a great potential of its application. And the data generated by the system can be relied upon, and this will give a good very good

method. This will form a very good method of quality analysis are. The most important thing that is it is a nondestructive method and once the process is (Refer Time: 31:06) and libraries greater, then it can be done more frequently and routine manner.

This I thank you very much.