**Novel Technologies for Food Processing and Shelf Life Extension**

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**Lecture – 45**
**Grain Storage**

Hello everybody, now let us study Grain Science and Technology subjects related to the grain in the next 2 3 classes or may be all 5 classes. In this week we will devote on this aspect which will include different matters are processes related to the storage of the grain, what are the various factors that cause the spoilage of the grain, how to measure the grain quality infestation in the grains and so on.

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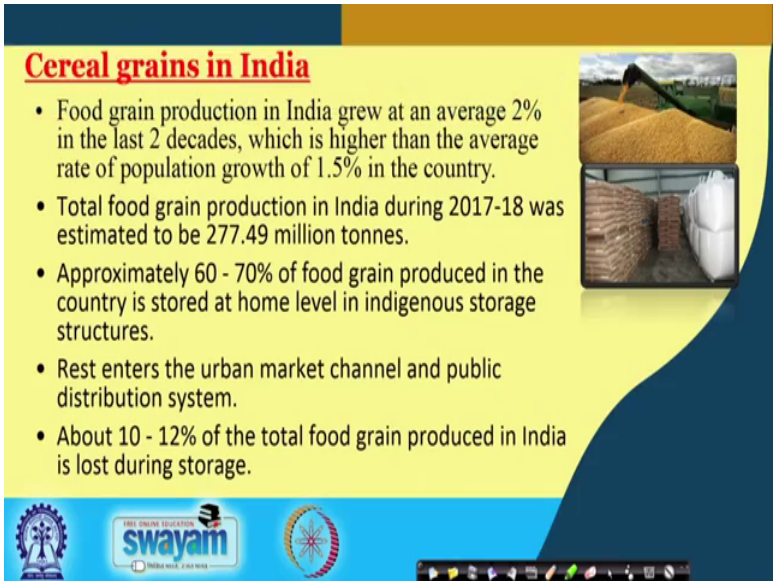


So, in today's class we will study Grain Storage, hope you know the situations of cereal grains in India, I will start lecture in this. If you look at the data available on food grain production in India we can generally we find or it generally shown that the production of food grains have grown on an average 2 percent in the last 2 decades or so. And which is higher than that of the average rate of the population growth in the country, which is generally which about 1.5 percent. The total food grain production in India during the year 2017-18 was estimated to be 277.49 million tones. Approximately 60 to 70 percent of the total food grain produced in the country is stored at the home level, in indigenous storage structures.

So, the indigenous storage structure etcetera also become very important component; rest around 30 to 40 percent enters the urban market channels and public distribution system. So, in the process whether it is the if you at total that is in the storage home storage as well as in the market channels or public distribution system it is estimated that on an average basis 10 to 12 percent of the total food grain produced in the country is destroyed; as last during storage and this is a significant loss.

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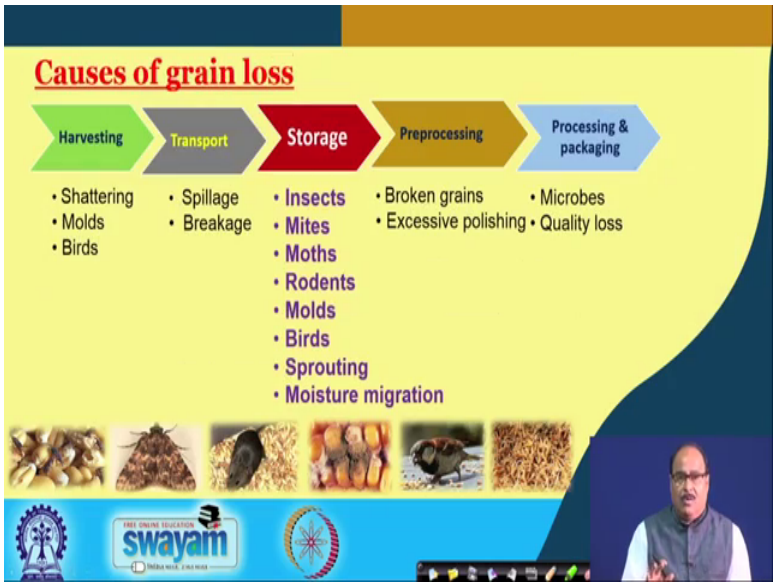


So; obviously, one need to take appropriate measures to reduce these losses obvious. So, means that is at least storage condition proper storage conditions etcetera should be maintained, so the losses are minimized if not completely eliminated. So, let us see the various factor in the total value change of the grains that is starting from harvesting, and to the its processing and packaging various factors operate and the various different losses types of losses like in the case of harvesting there maybe shattering, there may be loss due to molds and birds attack in the transport spillage loss breakage losses etcetera.

So, in all the like harvesting transport processing preprocessing or post processing packaging and storage various that is stages to which grain passes through if you compare you will find, that is during storage it is the maximum loss or the maximum factors that is problem takes place. So, in the storage it may be insect attack, mites attack, moths, rodents, molds, birds, sprouting, moisture, migration etcetera are the different factors which cause the loss of the grain in storage during storage.

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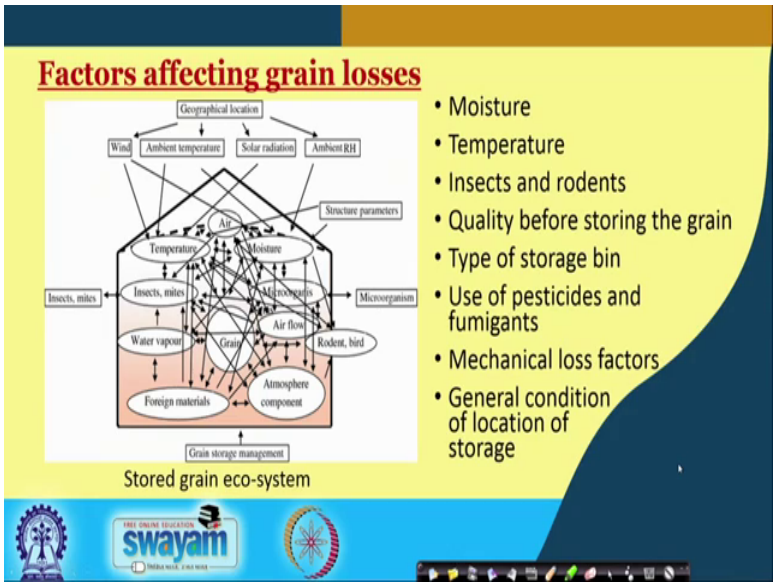


So, in this picture we have seen the stored grain ecosystem; when the grain is maintained in any conditions. There are various factors that is the ambient conditions, conditions inside the storage atmosphere, conditions of the grain that is if the moisture is more moisture is less grain that is the respires it produces heat it might produce carbon dioxide it may can do. So, there are different interactions there may be the grain temperature inside that is maybe more or less. So, different interactions and all this interactions may facilitate or may cause problems in the growth of the insect at may its microorganisms etcetera.

So, basically it becomes an important aspect to study that is the grain ecosystem that is how the interactions between various component let us see you can see here that is wind, solar radiation ambient air ambient temperatures. Then inside this grain and the continue all this thing that they it will influence the or it may provide conditions favorable it may provide conditions unfavorable for. So, accordingly that is storage facility is a selected and then environmental desired environment to control the growth of insect mites microorganisms alright etcetera like conditions.

Which favor is growth like moisture temperature insects and rodents that is these etcetera these are the factors which influence the grain losses as I told in earlier slide also that is. So, quality before storing the grain type of the storage bin use of pesticide and fumigants, mechanical loss factors general conditions of the location of the storage godowns

etcetera, all this are the factors which influence the grain losses and accordingly these factors they maybe more, they maybe high depending upon the storage ecosystem. So, it is very very important to maintain a proper ecosystem inside the storage facility. So, as to for minimize the effect of this factors on the grain loss.

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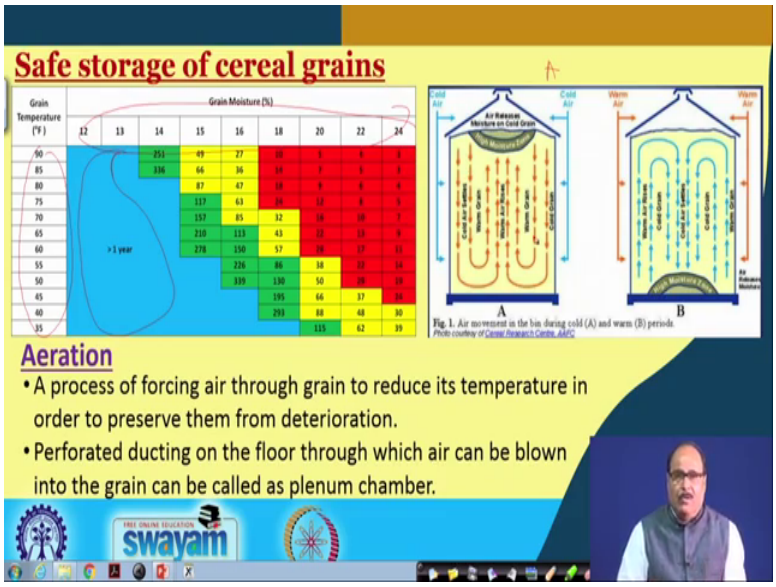


In this slide you can see that these are the conditions that is the conditions for safe storage of cereal grains. That is how the self life or storage life of the grain varies with the temperature, as well as its moisture content and; obviously, if the temperature is more relatability is also high it has comparatively less self life ok. Temperature is more relatability is high it has comparatively that is less self life its temperature is less its humidity is also reduced. So, its self life will be more. So, you can see here even 12 to 13 percent that is the moisture content, is the one which gives self life more than 1 year; even are the temperature 90 to 35 degree Fahrenheits.

So, it becomes 13 percent it becomes 12 to 13 percent is safe moisture content for the storage of the cereal grains. And to maintain the storage ecosystem aeration is one important process you will come in the toward the end of the lecture also on this aspect, that is a process of forcing air through grain to reduce its temperature in order to preserve them from deterioration. And perforated ducting on the floor through which the air can be blown into the grain, they are used and this can be is generally called plenum chambers etcetera.

In this slide see here how the aeration that is whether depending upon the temperature ambient conditions, outside is more or high accordingly one has to have a cold air system or warm air system and movement of the airs, air movement in the storage bin that is the first a is the warm and b is the that is the cold is a and b in the case of b it is the warm air and the movement of the gases accordingly. That is inside the grains etcetera which are there that is easy movements of the air facilitate for the proper control of the temperature and therefore, that it prevents the insects and mold growth etcetera.

So that becomes very important, that is the storage ecosystem as well as the conditions (Refer Time: 10:05) this for minimizing the losses are increasing the self life.

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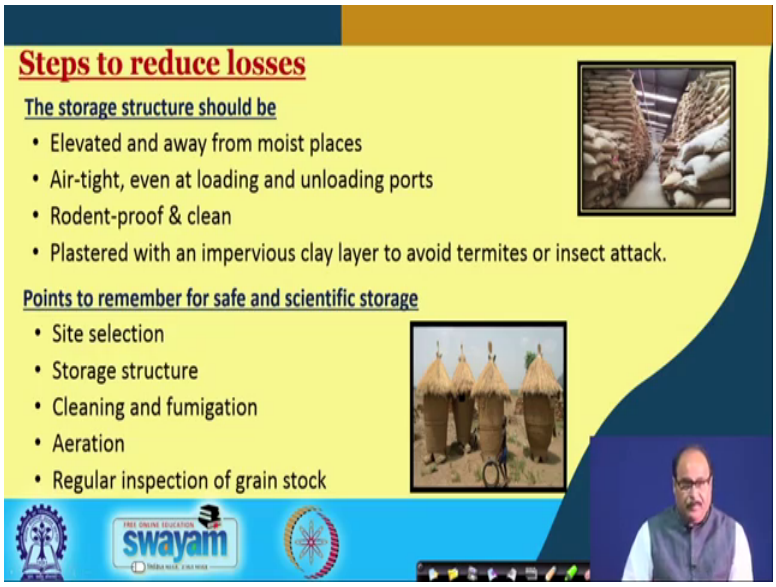


So; obviously, that is we should take appropriate steps like, the appropriate storage structures should be used for maintaining proper ecosystem in the storage facility. And these are the major steps to reduce the storage losses. So, some consideration for the storage structures that is it should be elevated and away from the moist places.

So, that the proper maintenance of the safe moisture inside the storage facility can be facilitated, the storage structures should be air tight even at loading and unloading ports. It should be rodent proof and clean, and it should have plastered, it should be plastered with an impervious clay layer to avoid termites or insect attacks. The points that one should remember for safe and scientific storage of food grain are the site selection that is the proper site conditions around in the storage facility etcetera, storage structure that is

type of this storage structure, the cleaning and fumigation aeration and regular inspection of the grain stock. That is how the quality is maintained inside the storage facility. These are the some of the important steps important points that are required to be noted down or that step that are required to be taken in order to reduce the grain losses.

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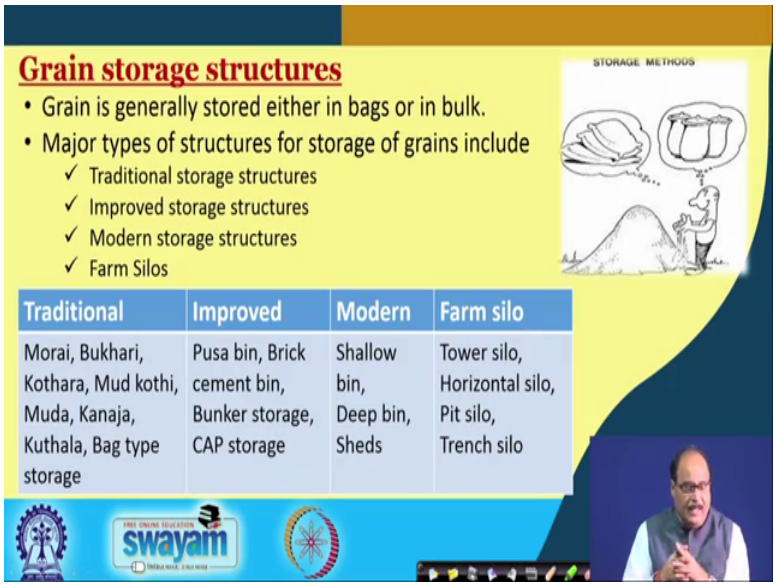


Now, let us study the different types of grain storage structures storage structures which are used traditionally as well as scientific storage structure, especially with especially with especially aspect to our country in India. That is a grain is generally stored either in bags or in bulk. So, the major types of structures for storage of grains, include traditional storage structures, improved storage structures, modern storage structures and farm silos are structures.

Which are made on farm storage structures we can say the traditional storage structures normally include morai, bukhari, kothara, mud kothi, muda, kanaja etcetera. Improved storage structures include pusa bin, brick cement bin, bunker storage, CAP storage and so on. The modern storage structures include shallow bin and deep bin or even sheds and farm silos include tower silos, horizontal silos, pit silos and. so on. So, in the next slide one by one we will have little details of these storage structures.

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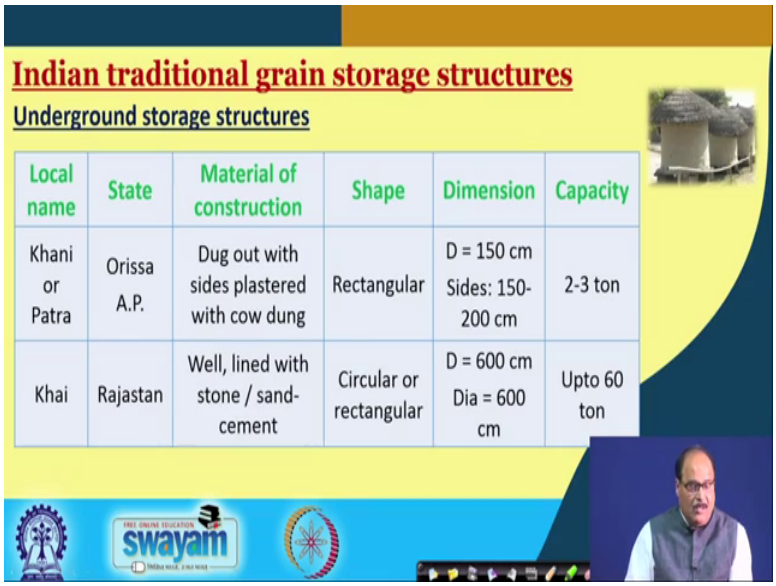


So, Indian traditional grain storage structures, there is in this one category is the underground storage structures, here in this table I have try to give you some common or important underground storage structures their local name, the state where they are popular for example, khani or patra they are the underground storage structures which are popular in state like Orissa and Andhra Pradesh. They are dug out with sides plastered with cow dung, they may be of rectangular shape having the diameter maybe dimensions depth 150 centimeter sides, 150 to 200 centimeters and the capacity may vary from 2 to 3 ton.

The khai which is a popular in a state like Rajasthan it is some sort of well dig dug inside under in the ground or underground it is lined with stones or sand cement, it maybe circular or rectangular its depth may be 600 centimeter diameter also may be 600 centimeter in case of circular well. The capacity may be up to 60 ton or so.

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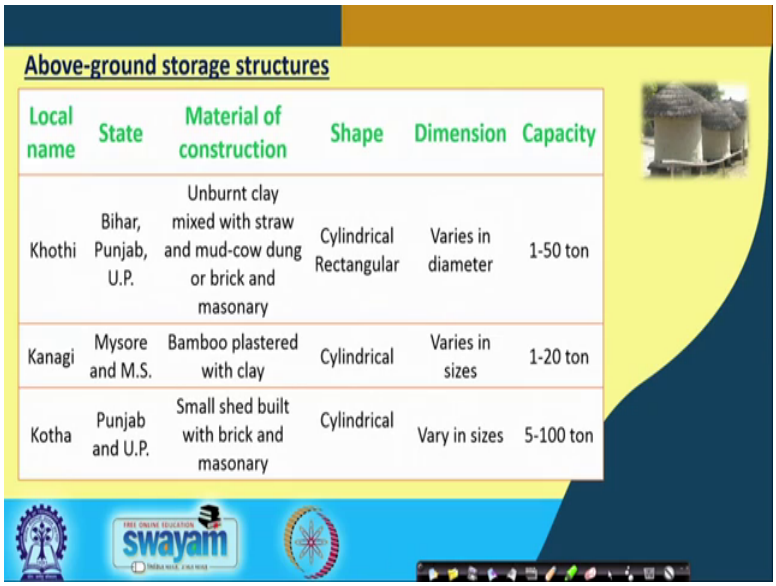


Above ground traditional structures include the Khothi which is popular in states like Bihar, Punjab, Uttar Pradesh etcetera they are made from unburnt clay mixed with straw and mud cow dung or brick and masonary work. They may be cylindrical or rectangular in shape their capacity may be vary from 1 to 50 ton and accordingly dimensions may also vary.

Kanagi which is in the Karnataka or Mysore region or in Maharashtra state they are made with Bamboo plastered with clay there may be normally is cylindrical, their capacity may be 1 to 20 ton. Similarly Kotha is the popular above ground storage structure in the states like Punjab and U P. They are made from small shed that is the this small shed built with brick and masonary work they may be cylindrical in shape and its capacity may vary from 5 to 100 tons accordingly dimension are vary.

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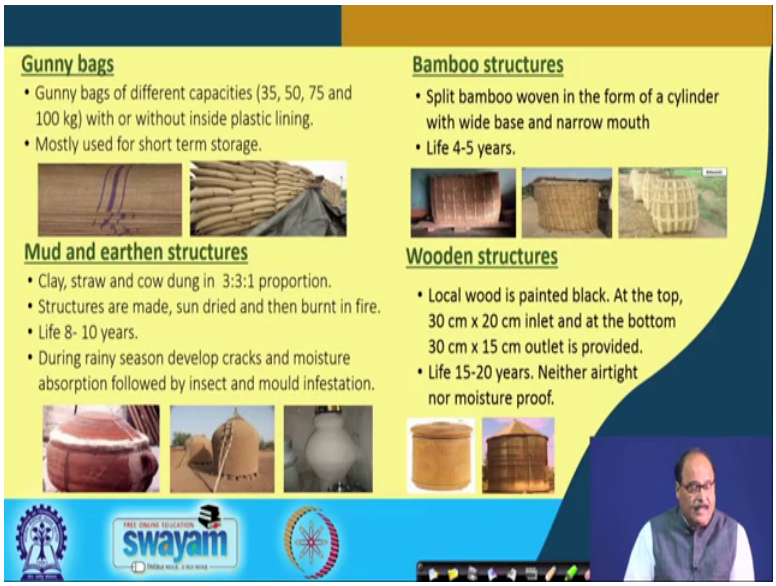


The other Indian traditional structures may be gunny bags the bags of different sizes ranging from 35 50 75 100 k g; they are used with or without plastic lining that is mostly they are used for short term storage of grain, they are stacked grain put in this bags are stacked one above the other you can see in the figure here. Then the mud and earthen structures which will different structures of the type in different part of the country which are used, you can see in this figures they are normally made with clay, straw and cow dung.

That is these three materials in the proportion of 3 is to 3 is to 1 is used for making them. And these structures are made sun dried and then burnt in fire, their life maybe 8 to 10 years. And hour during rainy season they might develop cracks and the moisture absorption is inside the grain is followed with insect and mold infestation. The other type of structure Indian traditional structures may be bamboo structures you can see here in this figures, split bamboo woven in the form of a cylinder with wide base and narrow mouth.

Their life is spend maybe 4 to 5 years, the wooden structures are made by using local wood and they are painted black at the top about 30 centimeter to 20 centimeter inlet. And at the bottom about 30 centimeter to 15 centimeter outlet is provided. And the life of these wooden structures may vary from 15 to 20 years depending upon the conditions of

the localities surroundings and also how they are used, they are neither airtight nor moisture proof.

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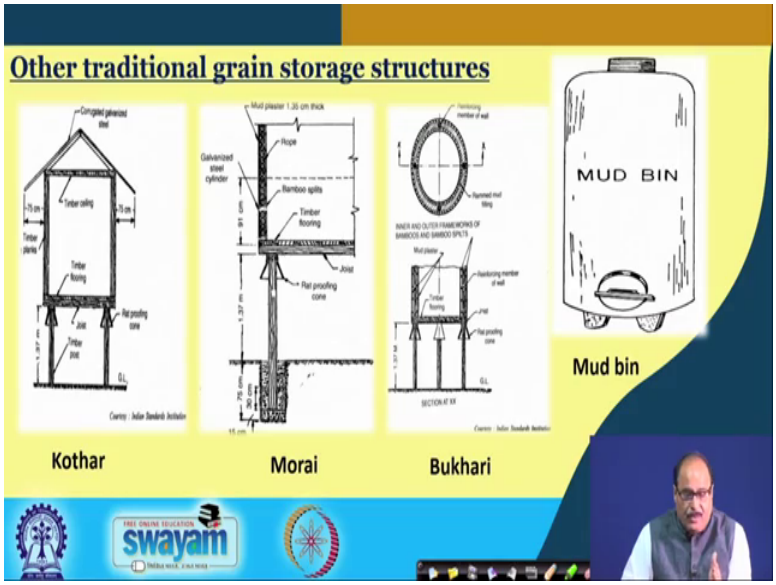


So, other traditional grain storage structures may be kothar, morai, bukhari, mud bins etcetera which are used or which are common or popular in different parts of the country. And in this figures you can see that is what is their layout and how they are made their dimensions etcetera are provided sometimes they are used. The bamboo splits are used in other case that is timber ceiling maybe provided, some inner and outer frame works bamboos and bamboo splits so and mud bin maybe used with the that is muds etcetera clay although.

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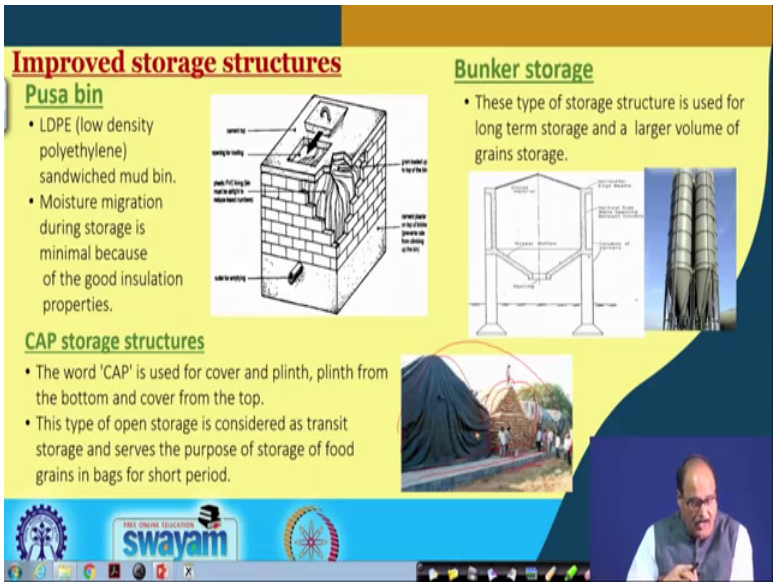


So, these are different types of Indian traditional, but of course, these structures are not very effective. As you can see they have all one or the other problem like the moisture maintenance aeration and all those things are difficult and then accordingly the grain quality which is kept in these structures is not very good or sometimes they do not have very good self life.

So, the drawbacks of those Indian traditional structures, have been overcome or removed by suggesting or by through means of by means of this improved developing improved storage structures like the pusa bin you can see here in this picture, that is it was developed by pusa institute ok. Here low density polyethylenes which are sandwiched with mud are used for this bin moisture migration during storage is minimal because of the good insulation properties of this bins so the moisture migration or moisture maintenance humidity etcetera.

Which is one of the problem in the traditional storage structures is to some words to some extent is overcoming this. Another is the CAP storage structure that is CAP means cover and plinth that is plinth from the bottom you can see. Here in this structure there is the some sort of plinth is provided for keeping this grain bags etcetera; so, plinth from the bottom and then cover from the top.

So, this they are covered with some plastic or some tarpaulin etcetera. So, this type of open storage is considered as transit storage. And serves the purpose of storage of food

grains in bags for short period; then the other is bunker storage, this type of storage structure is used for long term storage and also and comparatively larger volume of the grain is required for storage. So, for this bunker storage becomes a good structure.

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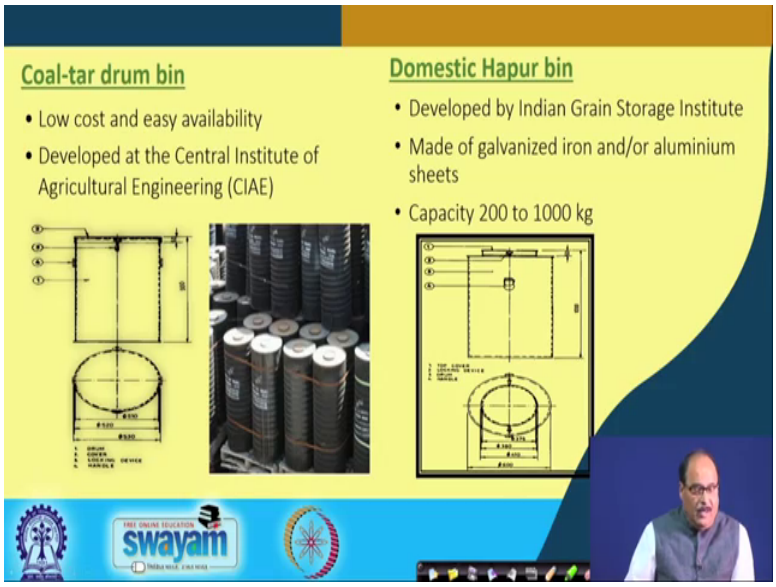


Then the coal-tar drum bin for improve structure this another consider that is it was it is a low cost and easily available material coal tar drums it was developed by Central Institute of Agricultural Engineering right CIAE and the dimensions etcetera are provided here. You can see these are the different drums the grain is a put into these coal tar drums and they are stacked one above the air the domestic hapur bin which was designed by this Indian grain storage institute. It is made of galvanized iron and or aluminum sheet and its capacity may vary from 200 to 1000 k g grains.

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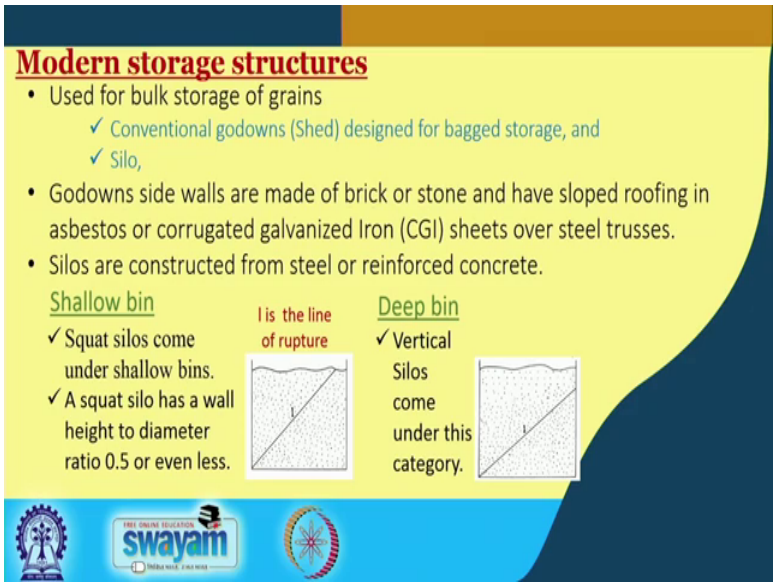


After that now let us discuss modern storage structures we have discussed common Indian traditional structures improved structures. And then modern storage structures and these are normally used not only in our country, but also in several other countries; globally they are used for bulk storage of grains and they include conventional godowns that is sheds designed for bag storage. And then silos, the godown side walls are made of brick or stone and have sloped roofing in asbestos or corrugated galvanized iron sheets over steel trusses.

Silos are constructed from steel or reinforced concrete they may be of 2 types maybe shallow bin or deep bin. Squat, silos come under shallow bin, and a squat silo has a wall height to diameter ratio of 0.5 or even less in the vertical silos come under the categories of deep bin you can see this in the picture, l is the line of rapture now in the case of shallow bin where is the line of rapture in the case of deep bin line of rapture is little below. So, this categorizes that shallow bin and deep bin one can say.

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The bulk storage of food grain normally in India is care by various agencies are there like food corporation of India central warehousing corporation, state warehousing corporations, grain marketing cooperatives, state government agencies are nowadays many other nongovernmental organizations also are coming into this. Practice and these are which agency generally which regulator which take care of the bulk storage of food grains. And obviously, the bulk storage has the is provide certain benefits like the running cost running storage cost or maintenance cost of the grain inside the storage facility etcetera.

Generally is low it results into the lower losses through spillage and rodents etcetera it is an efficient and effective system as far as the fumigation and aeration is concerned. It needs less land area and less labour requirements the aeration and fumigation that is even the complete control of the aeration and fumigation is possible here by having appropriate instrumentation etcetera. It is possible to store the grain for longer period of time, possible to store moist grain for short period of times and more importantly in the bulk storage structures that is the all the operations like loading, unloading, transportation etcetera. All those things this operations can be mechanized and. So, it provides better efficient and controls and also the lower cost etcetera.

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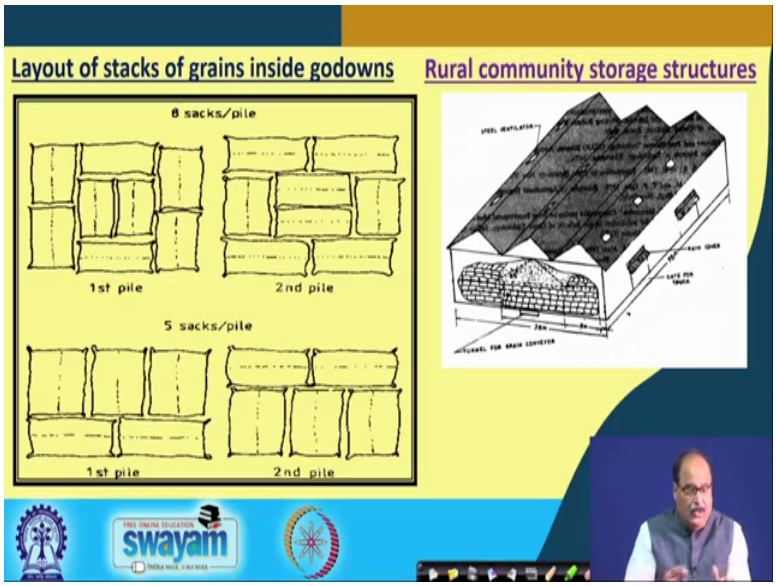


So, different in the different bulk storage you can say that is the layout of the stacks of grain inside the godowns is soon in this figure there may be a 8 stacks per pile that is the first pile second pile third pile fourth pile etcetera. In this first pile there is 8 stack in other 5 stacks. So, how that is this different bags they are stacked one above the other that is. So, they are provide the proper strength and also there is proper space for the aeration inside.

You can see1 2 3 4 5 like this, then stacks and proper space is provided. So, that not only for the movement of the air, but for the personal and the machinery for the loading and unloading. So, in this 8 bags are kept in one stack here the 5 bags 1 2 3 4 5 these 5 bags, but there is a proper space is maintained in with all the is to have a proper aeration. So, this type of some there is rural community storage structures are even in the urban area there in the on farm this can be maintained and these bags can be maintained inside storage. So, these are some of the systems or layout of a stack. So, for proper aeration proper fumigation and of course, this facility it will it is better. So, that it should be maintained leak proof.

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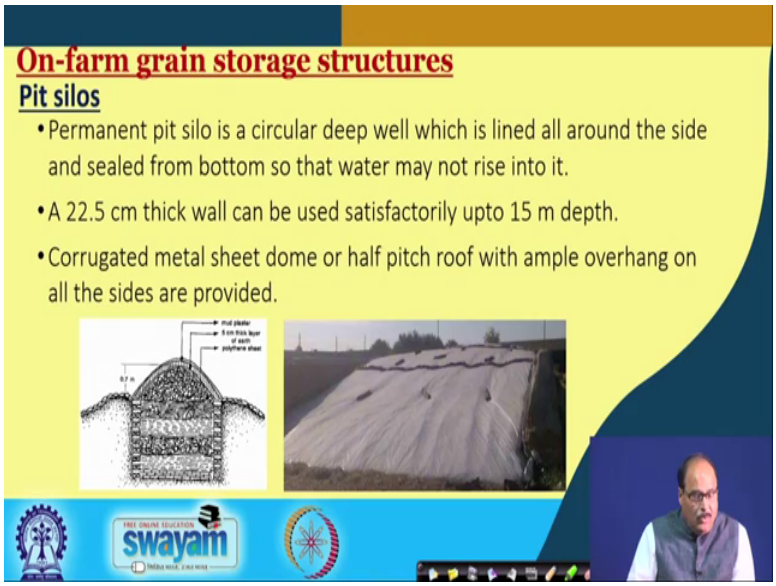


Then on farm storage structures include pit silos there is permanent pit silo is a circular deep well which is lined all around the side and sealed from the bottom so that water may not rise into it that is the soil water field water about 22 and half centimeter thick wall, is used and it becomes a satisfactorily 25 and half centimeter thick and it is it works satisfactorily up to 15 meter depth.

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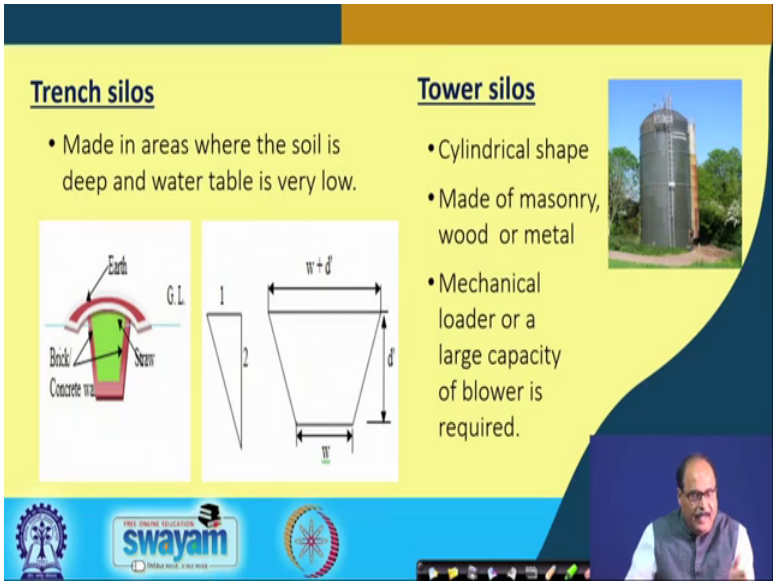


Corrugated metal steel dome or half pitch roof with ample overhang on the all sides may also be provided. So, you see here in this pit silos. The other are the trench silos which

are made in the farm or the field it is the areas where the soil is deep and water table is generally low this trench silos are made. Tower silos they are cylinder in shape made of masonry wood or metal the mechanical ladder because they are very tall.

So, generally mechanical loader or a large capacity of blower etcetera might be required to fill the material or to blow the air etcetera to maintain the proper air and temperature inside.

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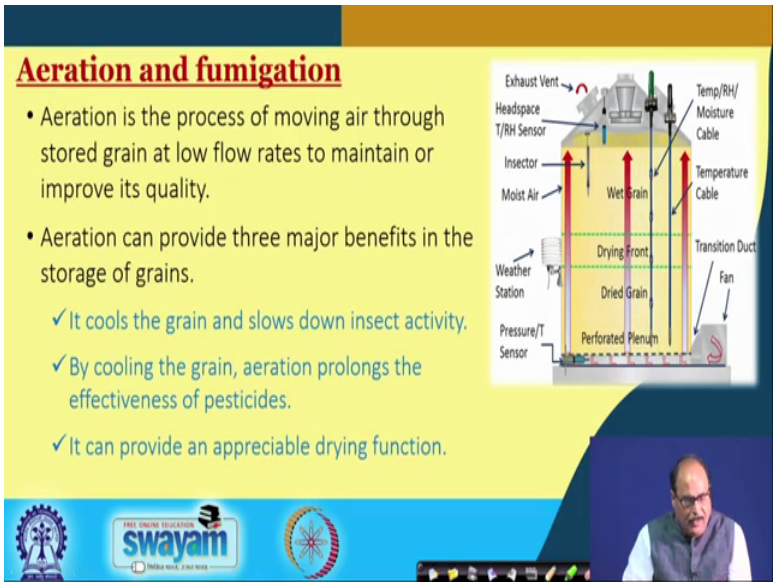


Aeration and fumigation as I told you earlier it is the process of moving air through stored grain at low flow rates to maintain or improve its quality. Aeration can provide 3 major benefits in the storage of grains it cools the grain and slows down insect activity by cooling the grain aeration prolongs the effectiveness of pesticides and aeration can provide an appropriate drying function as well. So, this in the grain the different facilities in the picture you can see that is how this different (Refer Time: 29:29) or the drying front they are maintained.

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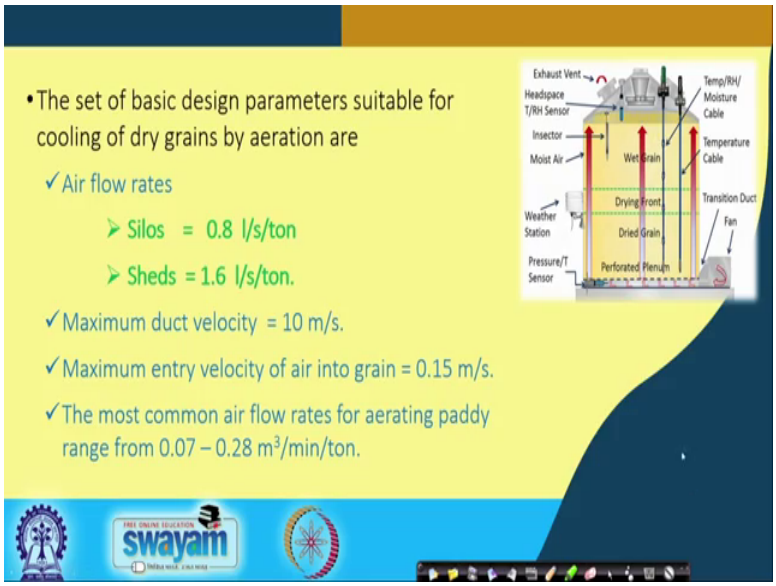


And also the set of basic design parameters suitable for cooling of dry grains by aeration are the air flow rate may be the in the silos point maybe 0.8 liter per second per ton, air flow rate might be required in the case of shed it may be just double or more than that may be the maximum duct velocity maybe 10 meter per second maximum entry velocity of air into the grain maybe kept 0.15 meter per second. And the most common air flow rate for aerating paddy ranges from 0.07 to 0.28 cubic meter per minute per ton.

So, depending upon the different types of grains their condition their humidity and all those thing what is the etcetera aeration, their aeration and fumigation etcetera should be decided.

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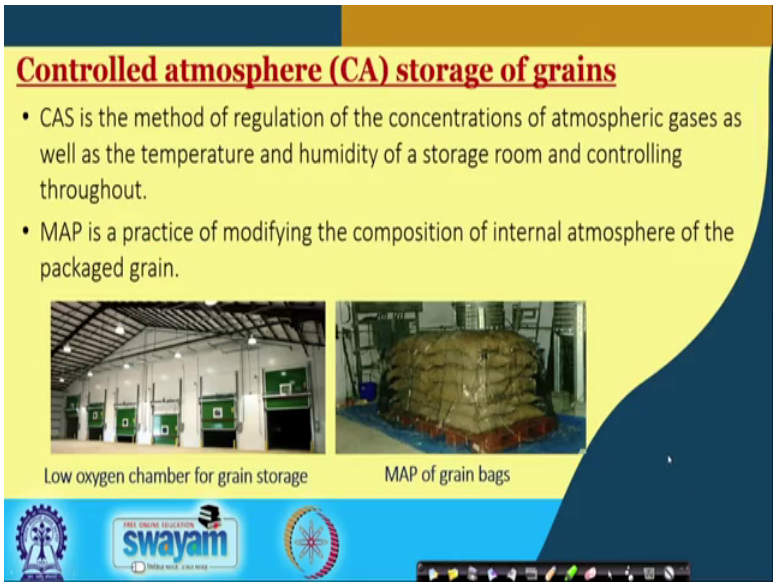


Then another important aspect is the controlled atmosphere, storage of grain as well we have already discussed in the earlier classes what the in the fruits and vegetables? What is the controlled atmosphere or how what is the modified atmosphere, but this can be applied as well to the grain you can see here that is low oxygen chamber of for the grain storage is shown in the figure.

So, if the oxygen chamber is low; obviously, respiration is less at lower rate heat generation will be less and the grain can be cooled for longer time and its self life. Similarly the modified atmosphere packaging that is in the grain in the different bags etcetera like poly bags another bags can be used where inside the bag the atmosphere is maintained and these bags are kept in some sort of storage environment.

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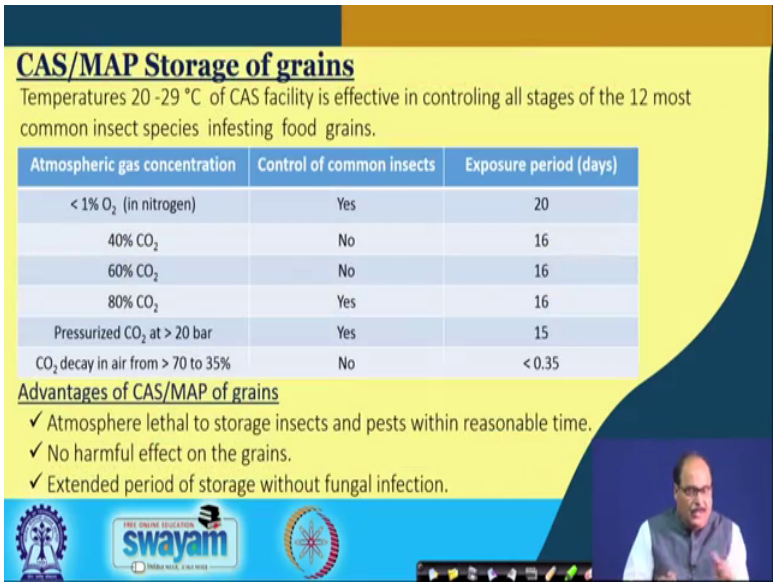


So, CAS MAP storage of grains the temperature normally is reported that 20 to 29 degree Celsius, temperature of CAS facility is effective in controlling almost all stages of the 12 most common insect species. Which infest the food grains that is in the table I have given that is like oxygen content less than 1 percent the nitrogen. It controls all the common insects pests and exposure time required to control maybe 20 in 20 days for 20 days.

Similarly, carbon dioxide concentration varying concentration 40 60 and 80 percent if they are given for 16 days; that is when it is 80 percent C O 2 it becomes effective in controlling. So, pressurized carbon dioxide at more than 20 bar it is a exposure period of 15 days it controls the common insects. So, CAS control atmosphere at storage are modified atmosphere packaging of the grains is a beneficial. Because it provides atmosphere it is lethal to a storage insects and pests within the reasonable time. There is no harmful effect on the grains extended period of storage is obtained without any fungal infection and so on.

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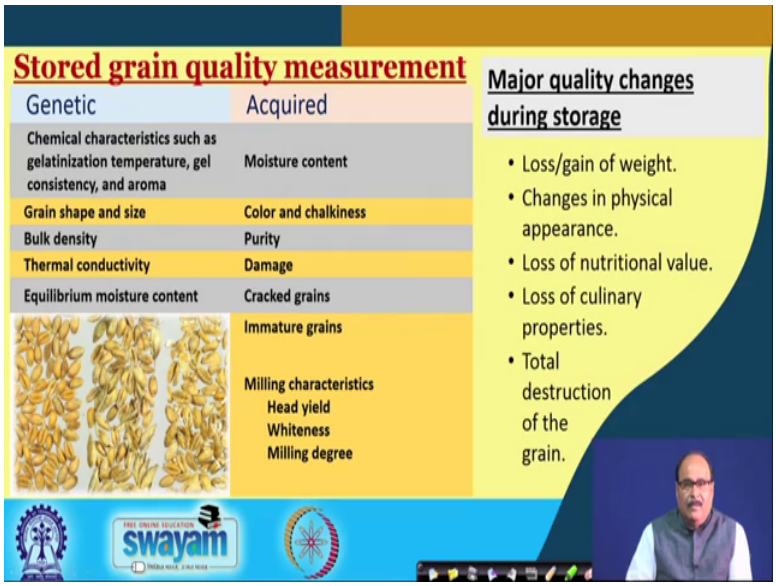


So, now there is a important another important that is stored grain should be analyzed for its quality; to know that is whether the grain is good or bad or it has spoiled. So, we will discuss this aspect in the next class as well maybe next or after that, but the various characteristics like genetic characteristics of the material like gelatinization temperature, gel consistency, aroma, grain shape and size bulk density thermal conductivity equilibrium moisture content.

Or acquired characteristics like moisture content color and chalkiness, purity, damage, cracked grain, immature grain or milling characteristics particularly in the case of rice etcetera head yield whiteness milling degree all these parameters are taken as a criteria to adjust the quality of the stored grain or quality of the grain. How this parameters are changing during the storage how they are maintained that should be analyzed properly ok. And if there is the major quality losses or quality changes in the grain during storage might be there may be loss or gain in weight depending upon weather moisture absorption has taken place are it has the grain has dried out.

There may be changes in the physical appearance loss of the nutritional value, loss of the culinary properties are sensory attributes or total destruction of the grain as depending upon the conditions.

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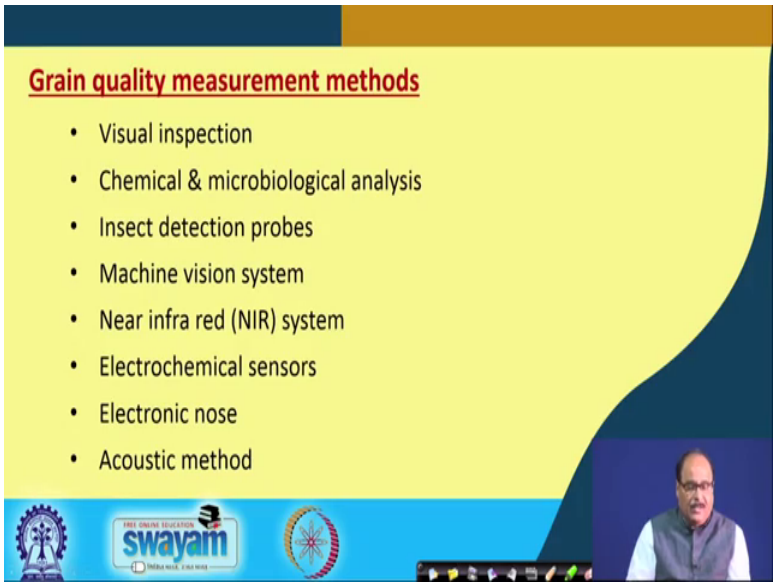


So, of course, there are different methods available in the literature are there methods are available which should be used to control the losses or check the quality. And they may depend upon visual inspection chemical and microbiological analysis insect detection probes can be used or machine vision systems near infra red or NIR system electrochemical sensors electronic nose acoustic methods etcetera.

So in fact, these methods or some of this important methods particularly the quick methods etcetera, we shall discuss their details in next class.

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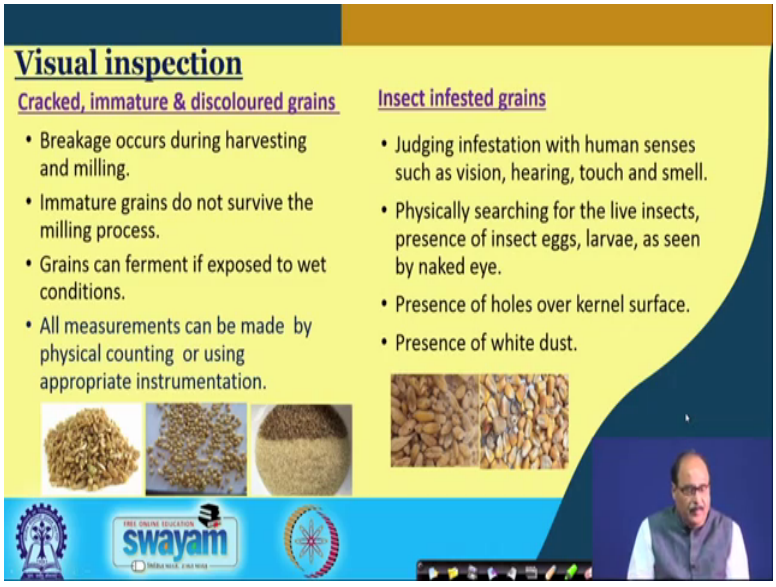

Then visual inspection methods normally used to detect cracked immature and discolored grains or even to find out insect infested grains, during storage or during other conditions. If they develop crack even in the field when they are harvested some grains may be immatured or some. So, by visual inspection or by manual methods they are removed.

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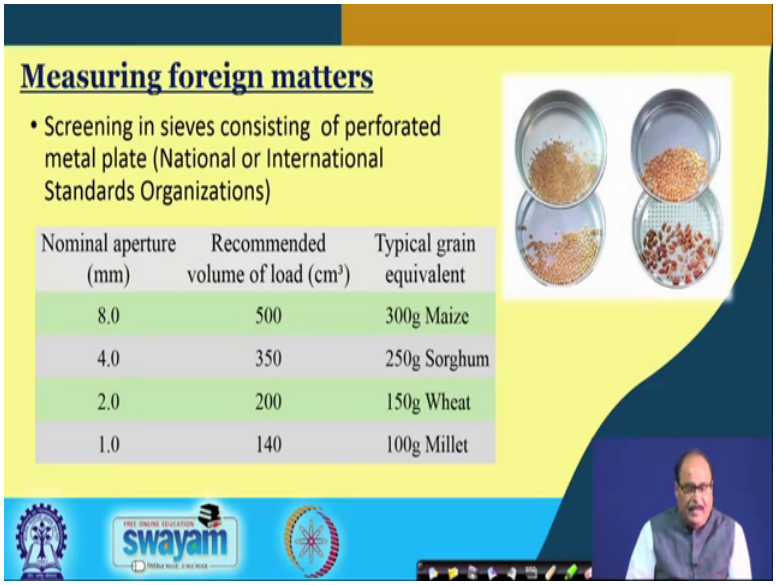


Then measuring foreign matters like screening of sieves consisting of perforated metal plates may be of Nationalized Standards or International Standard Organizations this different perforation different sieves are used. And then they can using this sieves the foreign matters etcetera can be sometimes stones etcetera which may get its may come or iron piece etcetera which might come from different harvesting or drying machines utensils etcetera are from the threshing or. So, they can be removed by using magnetic separators and all those things.

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Similarly, the moisture meter there are different types of moisture meters are available in the market like NIR based moisture sensors, infra rate based moisture rate sensors and other sensing probes etcetera are available chemical method is available. So, depending upon that is whether chemical methods normally although they are provide good reliable data which is used commonly in the laboratory, but it is a time consume process.

So, quick quickly that is the various sensors or probes as you can see in this picture they are available and they can be work on NIR technology or such other technologies. They can measure the even they can be used for online measurement of the moisture in the. So, the fact has to be consider why selecting a moisture meter; obviously, there is a it depends upon what is the resolution of the instrument and what is the level of accuracy provided by the data reliability of the data repeatability, stability, range of commodity and range of the moisture content which it can efficiently measure sample size sample weighing, ambient effect etcetera.

So, with this I think we have a good coverage of the grain storage structures, different types of a storage structures which are used traditionally as well as improved storage for the grain at the end. The most important thing is that the storage structures should be properly the conditions inside the storage alright, depending upon the grain as per the depending upon the requirement of the grain proper ecosystem should be maintained. So, that the grain self life is maintained to the maximum level. Its a is prevented from the

insect based another attacks and also the quality of the grain should be monitored as should be measured periodically to access the level of the spoilage are how it is or its a finding out its self life or its usability.

Thank you very much.