Advanced Aquaculture Technology
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Lecture 47
Smart Aquaponic System

Hello everyone, welcome to the second lecture of module 10 technology of cleaner production. My name is Professor Gourav Dhar Bhowmick, I am from the Agricultural and Food Engineering Department of IIT, Kharagpur.

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So, in this lecture material, I will be discussing about the introduction to the traditional aquaponic systems, the types of aquaponic systems, what is smart aquaponic systems and its components? And what are the challenges that we can face in smart aquaponic systems? And what are the advantages of going ahead with this kind of sustainable aquaculture units.

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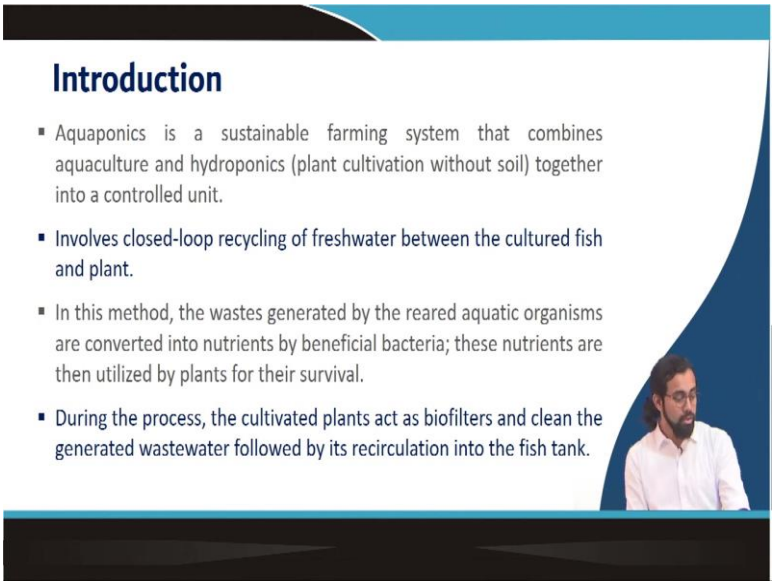

Aquaponics as we discussed if you remember in the last lecture also that it is a sustainable farming system that combines with aquaculture with hydroponics, plant cultivation without soil together into a control unit. It involves in a closed loop recycling of fresh water between the cultured fish and the plant.

And also in this method the waste that is generated from your aquaculture tank can be converted into the beneficial microorganisms and these nutrients are then utilized by the, these nutrients like they can be utilized by your plant of your hydroponic system for their survival. During this process cultivated plants act as a biofilter they clean the generated wastewater followed by its recirculation into the fish tank.

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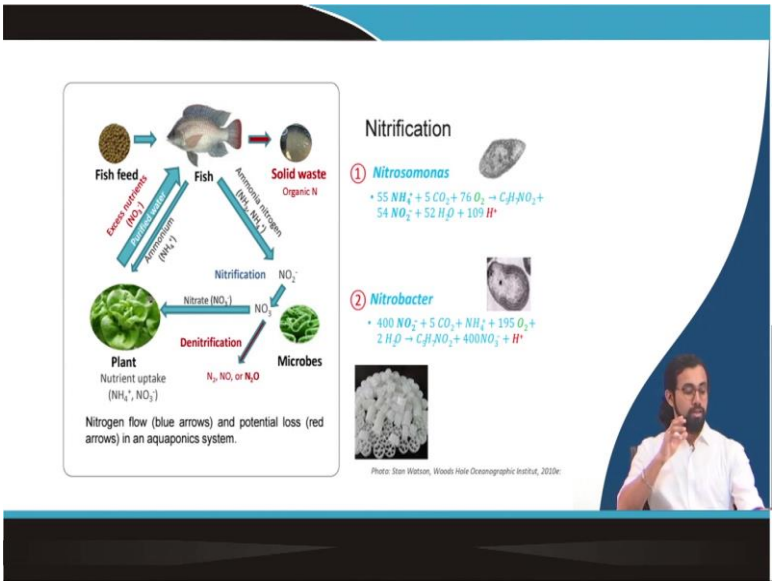

So, if you see this picture the fish feed you are providing with the fish feed some of them the fish they eat it and some of them they like in some of the fish feed that goes uneaten, solid it generates the solid waste or organic waste from the excreta of the fish.

What happens then? Then ammonia nitrogen like because of the solid waste this organic nitrogen convert into the ammonia nitrogen in general then this ammonia nitrogen is converted into the nitrate nitrogen and nitrite nitrogen then nitrate nitrogen because of the nitrifying or different nitrifying bacteria then this nitrogen is consumed by the plant.

And then it uses this nutrient uptake in the form of nitrate in general then, it again excess nutrient can be utilized by the fish also like it is or mostly we almost get rid of all the nutrients from the plant mostly it happens if you design it perfectly and then the water will go back to your aquaculture tank.

So, this microbes can utilize this nitrate and if that somehow it can provide it with the anoxic condition that denitrifies can also grow and it will consume this nitrate and it will convert it to the atmospheric nitrogen or nitrogen dioxide. So, this atmosphere nitrogen it will go away it will go and even like it will dissolve back to the atmosphere.

How does nitrification works, if you see the Nitrosomonas it acts on this ammoniacal nitrogen and then it converts into the ammonium ion and it will convert into the nitrite and this nitrite can be converted into the nitrate in the presence of nitrobacter. So Nitrosomonas and nitrobacter are the nitrifying microorganisms or nitrifying bacteria which are responsible

for the conversion of ammonia to ammonia nitrogen to nitrate, nitrate nitrogen and this nitrate nitrogen is being then being utilized by the plant in general.

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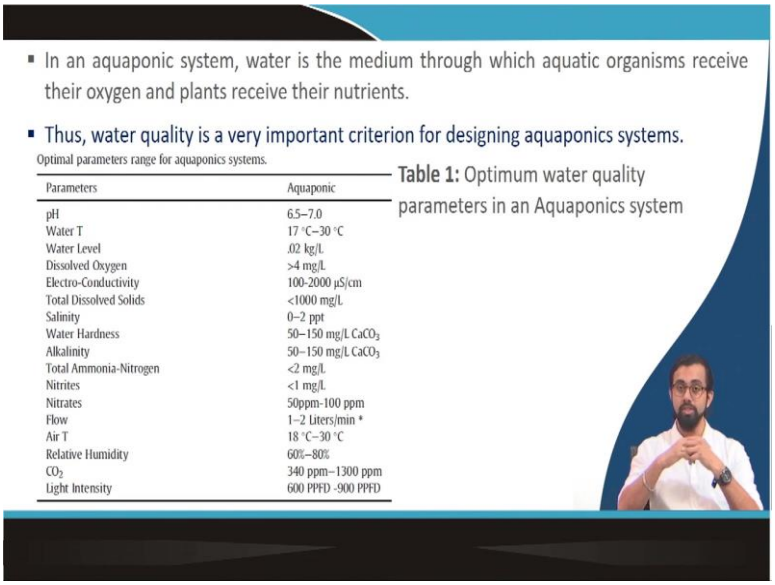

In general, the in this kind of aquaponic systems mostly water is act as a medium right here, we do not talk about soil because there is a soilless agriculture system. So, we talked about like water in general because water is the one which is the major factor here and which is actually contributing to all, it is actually supplying all the nutrients from one place to another.

So, the water quality is very important criteria like also like very important criteria for designing aquaponic systems. Optimal water quality parameters in an aquaponic systems if I talk about so, this is just a glimpse or just to give you one idea about what can be the range of water quality parameters in your aquaponic systems.

It is not always true you can have some slight variations depending upon your culture you need depending upon your design. So like the pH can be 6.5 to 7, Water Temperature 17 to 30 degrees Celsius to Water Conductivity 100 to 2000 Micro Siemens per centimeter, Dissolved oxygen more than 4 milligram per liter or PPM.

Water Hardness 50 to 150 milligram per liter of calcium carbonate same as Alkalinity, total Ammonia Nitrogen can should be less than 2 milligram per liter, Nitrite definitely should be less than 1 milligram per liter because it is very toxic for your any aquatic species, Nitrate can be 5200 PPM flow 1 to 2 liter per minute is optimal air temperature 18 to 30 definitely should not go more than that definitely there will be a temperature.

There should be not much of a temperature variance, Relative Humidity 60 to 80 percent carbon dioxide 340 PPM to around 1300 PPM. 340 PPM is around like almost in general in standard condition air does have and it can go up to 1300 PPM. So, still people are working in different organization research laboratories, how the increased carbon dioxide level can affect your plant production.

So, in general up to a certain increment in the carbon dioxide is actually beneficial sometimes for your plant, but it is also still debatable, like there are a couple of researchers they claim so, but there are a couple of researchers not the same way.

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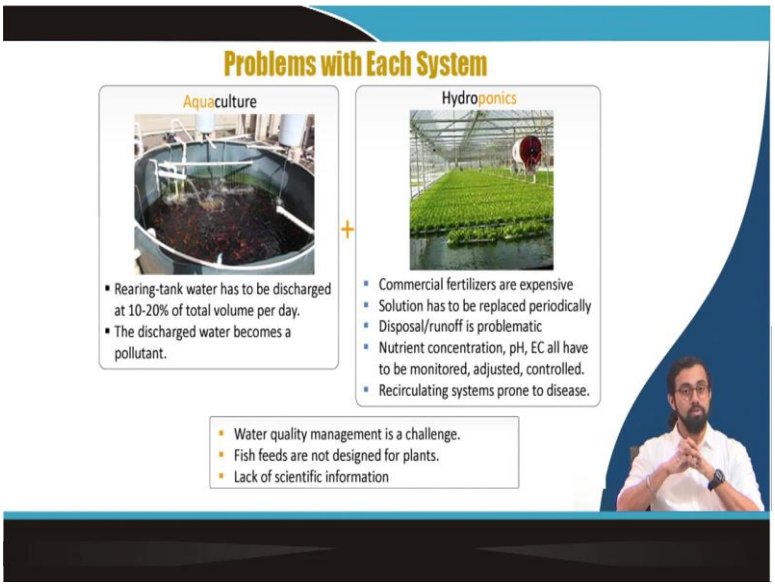

What are the problems with each systems and how it can be, like kind a reduce the salt or the troubleshooting in case of Aquaponics. In aquaculture, the rearing tank water has to be discharged at 10 to 20 percent of total volume per day it can go up to 50 percent so, it is like intensive aquaculture systems. The discharge of water becomes, the discharge water it becomes a pollutant.

So, you have to treat it and then only you can throw it back. In case of hydroponics the commercial fertilizers are expensive, solution has to be replaced periodically disposal and runoff is problematic nutrient concentration pH and electronic, electrical conductivity all have to be monitored, adjusted, and controlled and recirculating systems sometimes prone to diseases. All these problems can be troubleshooted by using aquaponic systems because in case of aquaponic systems like we can have we can reduce the water consumption.

Because the water is getting circulated back to the systems we do not have to worry about a discharge water because anyway it is circulating back. Commercial, instead of commercial fertilizer you are using aquaponic solutions, the disposable runoff is not a big issue then solution do not have to be replaced because anyway there is no solution that we are applying in general.

Nutrient the monitoring this different unit is anyway it is necessary in case of aquaponics also and somehow it can it can also reduce the overall disease related issues in case of Aquaponic systems.

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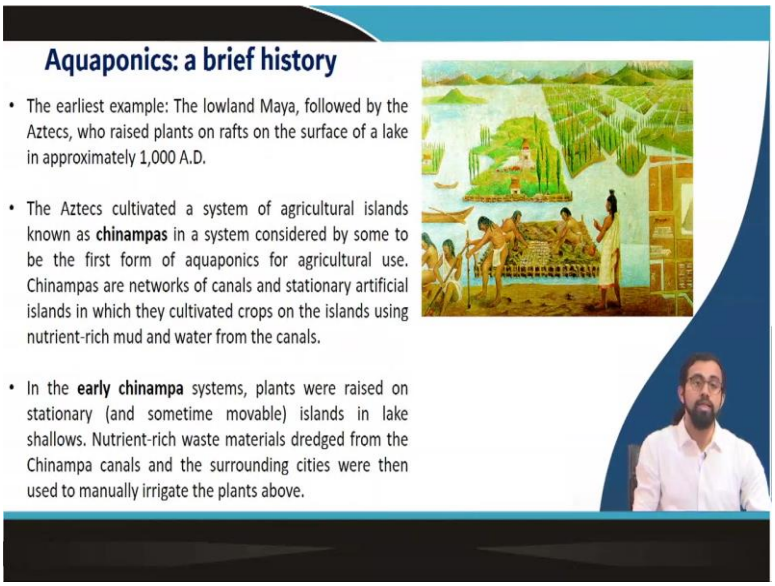

So, to start with, I want you guys to understand the history of aquaponic systems, it is not something that we developed 5 years 10 years back. The earliest example in lowland Maya followed by the Aztecs who raised we have found out like different pictures and holographic and then images and all where we found out images and archaeological evidences where it was… we are actually sure about the presence of this aquaponic systems is as long as 1000 A.D. And no domain you know it right.

So it is like in plants on the rafts and the surface of the lake actually they grow this any of these plants and all they know that if the plants are grown in raft in a surface of water body, what will happen? Is it will consume the waste, it will consume the nutrients from the water itself. And not only that, it will reduce the water contaminant load in your water body.

So plants can and though animals also can survive much easily. They call this islands this Aztec civilization we call this an island this Chinampas, it is a system considered by some of the first form of aquaponics for agricultural use. It normally it is a network of canals or stationary artificial islands, which are used to cultivate crops using nutrient rich mud and the water from the canal.

So normally the plants were raised in a stationary and sometimes movable in this early Chinampas and in the lake and shallow lakes and so on this nutrient rich waste materials dredged from the Chinampas canals and the surrounding cities were then used for manually irrigate the plants above.

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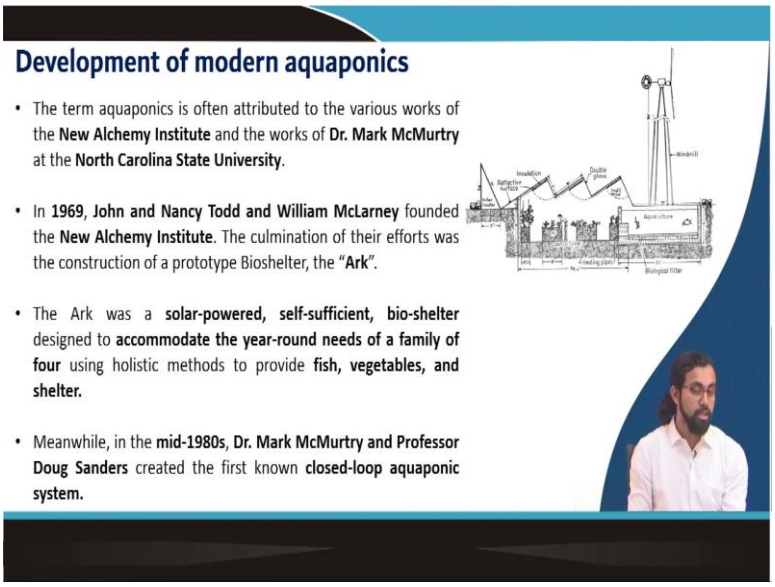

Development of modern aquaponics if I talk about the credit can go to New Alchemy Institute and the works of Dr. Mark McMurtry of North Carolina State University USA. So in 1969, John and Nancy Todd and William Mclarney, they founded this New Alchemy Institute and they found out they design a very famous prototype of Bio shelter, we call them Ark.

This Ark is a Bio shelter why he called Bio shelter? It will provide all the necessary needs for year round needs for a family of 4 using the holistic methods to provide fish, vegetables and shelter, they use a solar powered self-sufficient Bio shelter designed for accommodation of at least 1 family like for a family of 4 for a whole year.

And this standard model is like there they have introduced this aquaponic systems in there, they use the aquaculture wastewater to treat to utilize for your crop like, for their nutrient purpose. In the mid 1980s, this McMurtry and the Professor Doug Sanders, they created the first known closed loop aquaponic systems that we normally use now a days.

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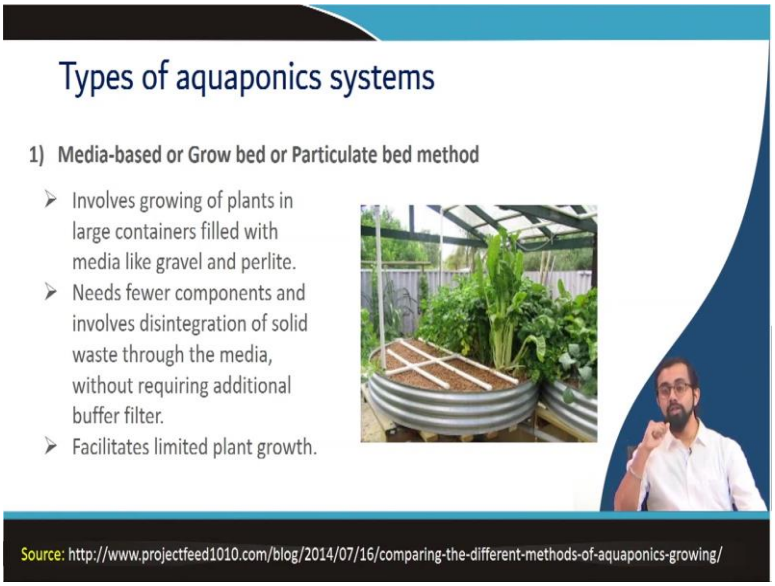

So, after knowing all the historical evidences and all let us go ahead with the type of aquaponic systems that are normally cultured there are like 10s of others, but we normally discuss about the major 3, the media based or grow bed or particulate bed method.

It involves the growing of plant in a large container filled with particles like in a gravels and the perlite an all and it needs very fewer components and this plants when you provide the what will happen it normally it involves the disintegration of the solid waste through the media without requiring any additional buffer filter?

It also facilitates the limited plant growth though however, it is possible and it is being drastically it is being like very much famous in all of our world in different purposes and this media are actually used for growing hydroponically, this plants and also the wastewater coming from the aquaculture tank can be treated there and this media actually works as a bio filter for treating those wastewater plus it is supplied to the aquatic your agricultural crops and these hydroponic crops.

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Second one is Deep water culture. In the Deep water culture or raft culture or floating systems, we use different rafts and then we put on a small containers like in a porous containers or jars where we keep our plants with the presence of some porous media and then this root system is attached to the shallow film of this or like sometimes deep film of nothing also a deep water like which is flowing underneath of it.

And the flow of water which is like continuous here and this water is actually provided with the either hydroponics solutions or aquaponics where aquaculture waste water. And they consume the water this root system is actually consuming the nutrient from the media from this deep water culture and they use it for their surviving purpose.

So, normally we use this Styrofoam which acts as a how to set this raft and all, additional securing can be done using the net grow pots in the holes below the by filing the clay or coconut media and the plant substrate. It involves the utilization of filters throughout the cycle to ensure appropriate recirculation. And also it is the highest producing aquaponic system techniques because of its design, as the raft can cover a huge amount of space and can be reused after harvesting the plants.

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Nutrient film technique, it involves the growing of plants within a narrow channel of like gutters or like normal pipe like structure. So, in this pipeline structure, there is a narrow water body which is like keep on flowing and this water line of plants are placed at a certain interval. It includes a continuous this thin flow of water supplying more oxygen and nutrients and which will help the growth of the root much better way.

It is though it is not a widely used aquaponic system sometimes because due to the risk of clogging by the generated organic waste. In case of aquaponic system technique I am talking about it allows only growing some very few small plants like the leafy greens without large roots to avoid the clogging and all it requires an additional biological filter, since the system is not exposed to air, it requires constant maintenance.

So, these are some issues with the aquaponic system. In general as a hydroponic systems, a standalone hydroponic systems nutrient film technique is very good, but for aquaponic systems it is better to go for a deep water culture the second one that we discussed.

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What are the fish generally used in aquaculture systems aquaponic systems Tilapia, Trout, Catfish, Bass, Goldfish, Koi, Pacu, et cetera. So you can definitely grow them and because one of the major reason to go for this carps and all like specifically and this Tilapia's and all, what they do they are actually they are susceptible to minor environmental changes.

So, suppose in general there is a chance of the treatment is not enough and they have they are sustaining in slightly poor environmental condition water parameters. Still with this certain increment in the pollutant level also the species can survive. So, that is the reason we go ahead with this kind of production with these kind of fishes and not only that, their biomass growth is also very high it can also you can have a very high economic benefit also if you grow this kind of fishes.

These are some of them they grow in different temperature levels that you need to maintain and based on your area of culture, if you are from temperate region, your area of culture is different in structural and design will be different, if it is from the equatorial region your design and expectations will be different, like different species will be there.

And also if you want to mimic environment in exotic environment in that you can also culture the temperate plants in temperate species in equatorial region or equatorial species in the temperate region. In general, the maturation size, the duration to reach maturity and oxygen requirement are the one which are very important in this matter.

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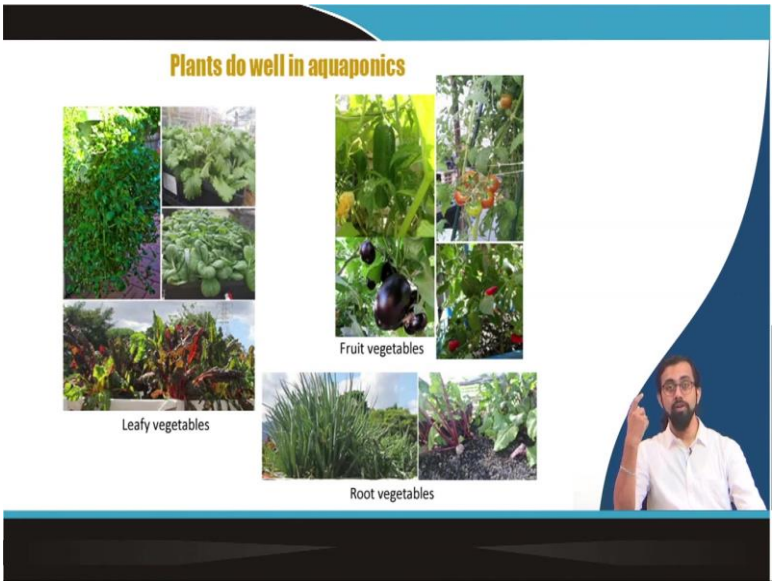

The plants which can do well in aquaponics, mostly the leafy vegetables, you can go the fruit vegetables, you can go ahead with some root vegetables and more than you can go ahead with different kind of horticulture crops also which an Ayurvedic crops also which will also give you very high benefit. If you go ahead with this kind of aquaponic system.

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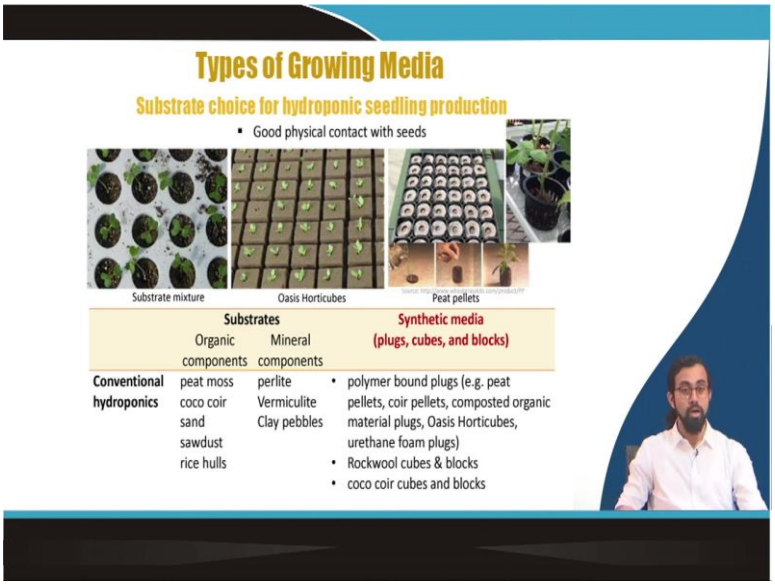

What are the types of growing media, we can go ahead with a Substrate mixture the Oasis Horticubes we can go ahead with the peat pellets. In case of conventional hydroponics we use this peat moss or coconut coir, sand, sawdust or rice hulls with the addition of perlite or vermiculite on the clay pebbles. In case of synthetic media, the polymer bound plugs like peat

pellets or coir pellets or composted organic, material plugs, can be used rock wool cubes and blocks can be used coconut coir cubes and blocks can also be used as a substrate.

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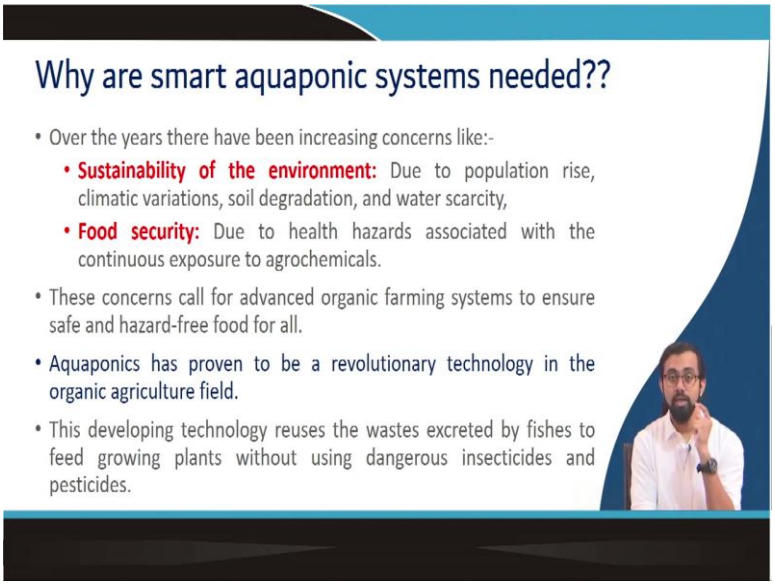

So, when we, we now know about what is aquaponic system, how it works, what can be the target species, like in terms of plant in terms of aquaculture species? So what is smart aquaculture system in that aquaponic system in this case? And why we need this smart aquaponic systems? With the smart only, nowadays, it is like smartphones, what does that mean? It keeps your life much easier, gives you real time data of different things.

So, whenever we use this smart with any existing technology, it means that you can monitor it you can like kind of real you can do the real time monitoring of the systems by reflecting the data of your field based, field based system to your mobile or any handheld gadgets. So that is when we call them smart systems in general.

So, over the years, this sustainability of the environment is a major issue and the food security or the things that we normally worry about. So all these concerns are actually let us ensure some safe and hazard free food production. Aquaponics is actually proven to be the revolutionary technology in this organic agriculture field.

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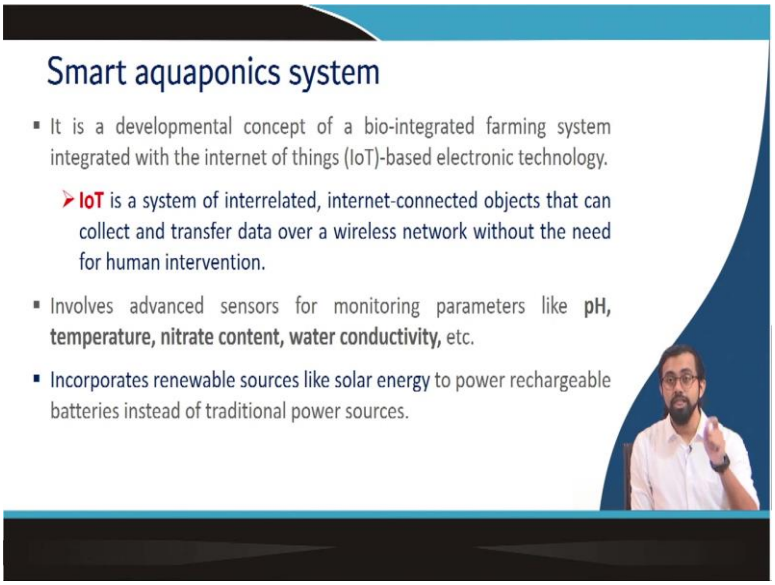

However, it also comes with some additional requirement of monitoring. This monitoring this development of concept of a bio integrated farming systems integrated with the Internet of things based electronic technology, we call them smart aquaponic systems. IoT is what IoT is a system of interrelated internet connected objects that can collect and transfer data over a wireless network without the need of human intervention. What are the data that we can get?

It depends upon the sensor that you have utilized. Suppose you have you put a CPH sensor in your aquaculture tank, you can get the real time pH data on your mobile all the time, temperature, nitrate content, water conductivity, ammoniacal content, et cetera. So you can you can get all this data to your system to your handheld gadgets. It incorporates the renewable sources of energy like solar energy to power the rechargeable batteries instead of traditional power sources.

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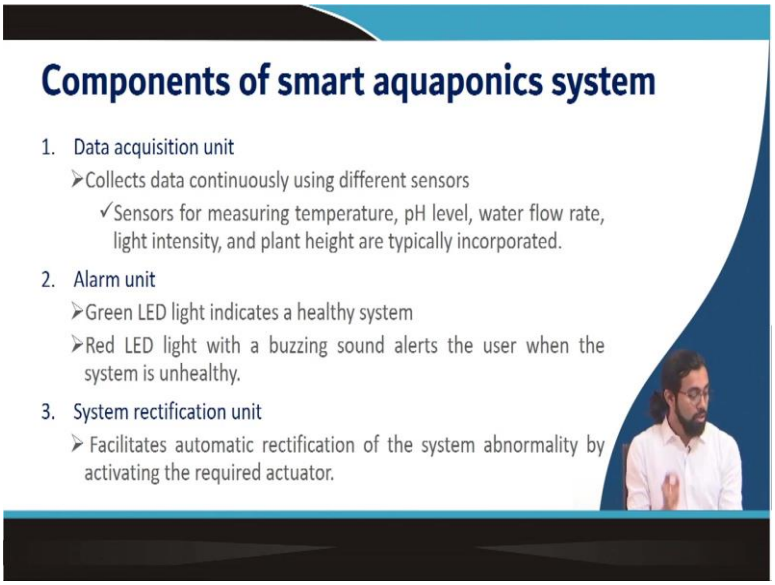

What are the components of aquacultural aquaponic systems first is data acquisition unit. This is nothing but the sensors. So, because it is sensors they continuously measure the temperature, pH level, water flow rate, light intensity over the crop, the plant height which are normally it is very much of our importance because you have this particle aquaponic systems where you have very limited space or landscape and where you want to grow it optimally.

So, all these information are necessary for you to get in real time manner, because you cannot just go and do the human intervention for say like one acre of land of Aquaponics systems you can do it in 10 feet by 10 feet of select 10 like small say like 10 square meter of area, but you cannot do it for 10,000 square meter of area, right.

So, like or say like 4000 square meter. So, all these cases, we have to go ahead with as less human intervention as possible. Alarm unit, the green LED light indicates the healthy systems red LED light with a buzzing sound it alerts the users when the system is unhealthy. System rectification unit it facilitates the automatic rectification of the system abnormality by activating the required actuator.

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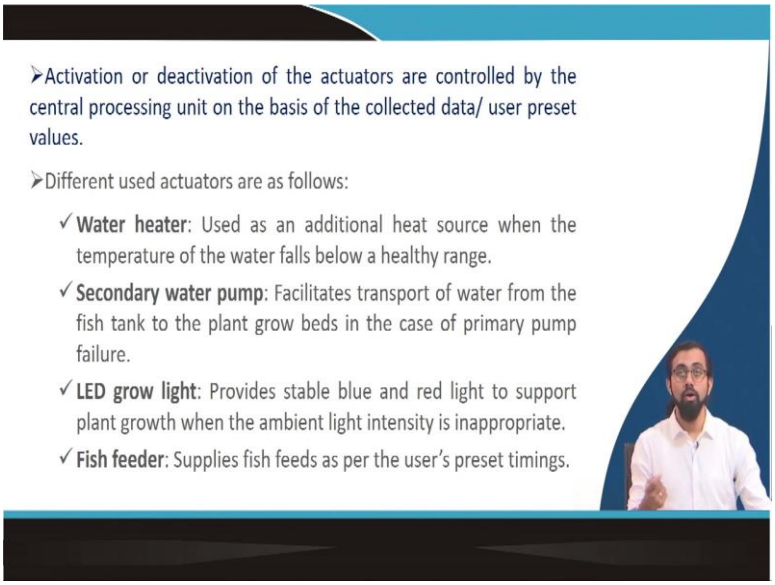

What are the actuators that we can have? We can have water heater, suppose your temperature goes below certain thresholds, water heater will automatically switched on or you can manually do it or you can or you can just simply put a button in or mobile and it will just you can switch it on. Secondary water pump, suppose somehow your water pump got affected and it is not somehow it is not working at its complete capacity.

What you can do? You can switch on the secondary water pumps to maintain the flow because just realize this you are dealing with a living being. This aqua this agriculture crops or this aquatic species they have life they need as because you are not letting them grow in their natural condition it is completely in your hand you have to control it you have to control their system so optimally that they will not be in stress at any moment of time, otherwise your production will be hampered.

So the LED grow light is also important to provide a stable blue and red light to support the plant growth when the ambient light and intensities are appropriate. Fish feeder supplies the fish feeds as per the user's preset timing. So, this activation and deactivation of this actuators are controlled by the central processing unit or CPU on the basis of the collected data or user preset data.

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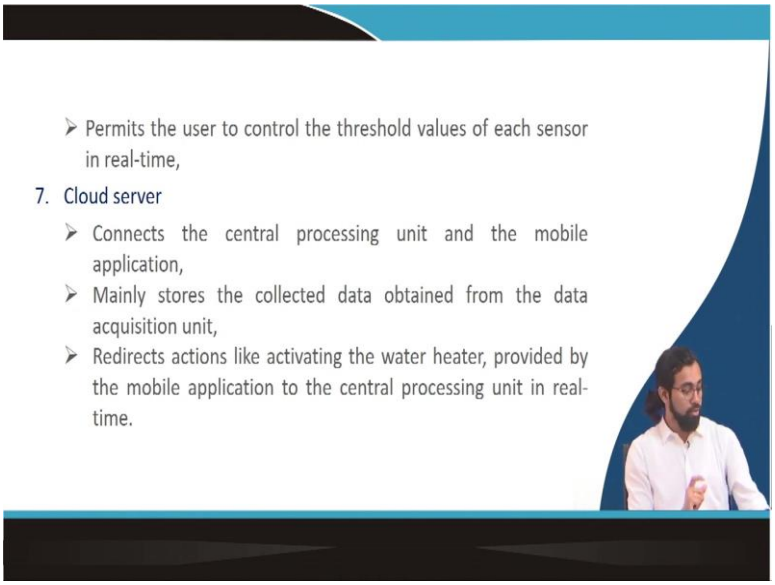

Fourth one is a central processing unit. It divides into 2 sections first, it involves and say Arduino Mega systems or like it depends I am giving you just 2 examples and a relay board to communicate and control the sensors and all the actuators. Also you can use a Raspberry Pi unit acting as a central control unit and a camera module to enable the live streaming features or like the amount of the plant growth that you can make can prove that you can monitor.

Fifth one you can go ahead with a wave application, it will provide you with the proper graphical user interface or GUI for the system to display or monitor the collected sensor values. It also facilitates the remote control of the actuators. So sixth is a mobile application it can be created on the Android or say like iOS based platform, it displays the live sensor values and it will enable the user to remotely control all the actuators that you have as, as I discussed in the last slide.

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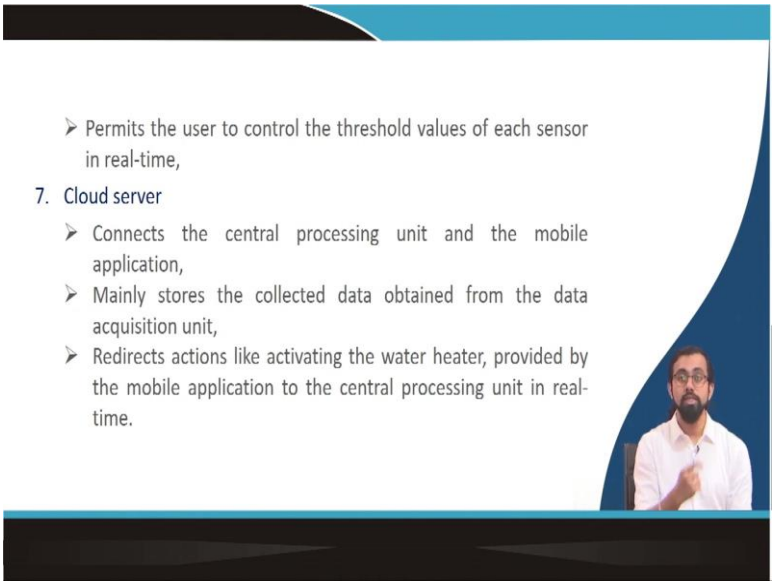

Also it will permit the user to control the threshold value of each sensor in real time. See seventh the last one is the cloud server why we need cloud server? It connects the central processing unit and the mobile application and it actually mainly stores the collected data obtained from the data acquisition unit and redirects the action like activating the water heater are provided by the mobile application to the central processing unit and it works like either way around.

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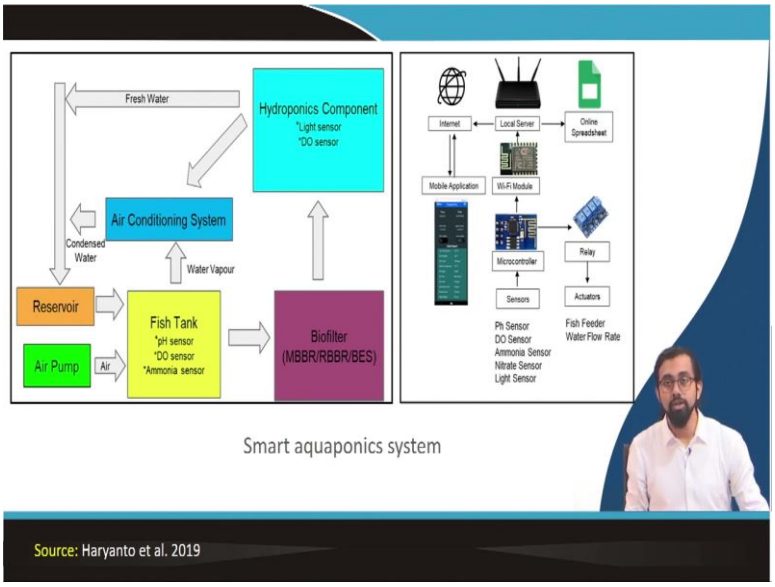

So, if you see this flow like we have this hydroponic component we can provide it with a light sensor, duo sensor we have air conditioning unit, which will… whatever the water vapor

and like evaporated water from the fish tank and transmitted water like this above transmitted water in general, from your tank from your system can go to the air conditioning system.

And the condensed water again flow back to the reservoir from the reserve it comes to the fish tank and the air pump is also continuously there to provide the dissolved oxygen to your fish tank. Your fish tank can have pH sensor, do sensor, ammonia sensors. So these sensors all the sensors you can it can be the tank water can be treated in the Bio filter.

It can be moving bed biofilm reactor it can be rope bed biofilm reactor it can be Bio electrochemical systems all this technology I have discussed in earlier modules. This Bio filter once it is converted into a preferable form of nitrogen then it will supply to the hydroponics system.

All these things can be how like can be modified into the smart aquaponic systems as we discussed you have this local server internet you can get, get all the data in your mobile applications, it can have this micro controller, the sensors and all will give the data to your micro controller, micro controller will ask the relay to control the actuators like fish feeder, water flow rate et cetera.

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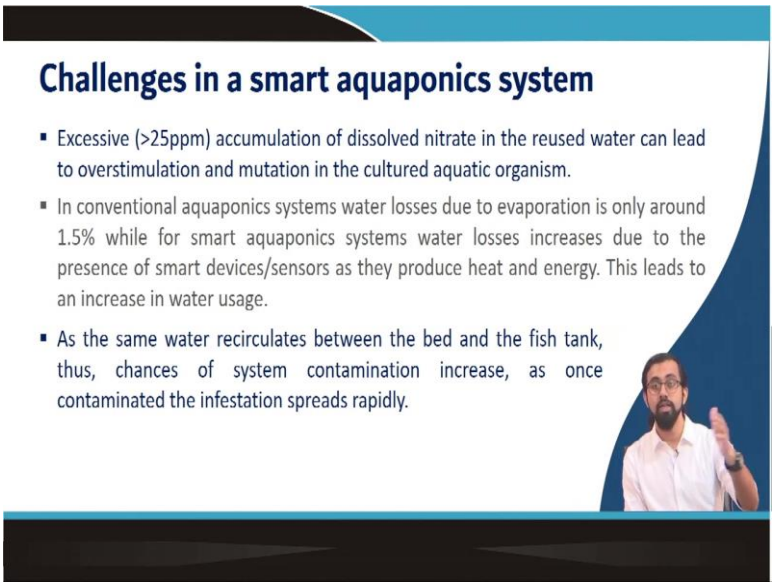

So, these are this is why it is called Smart aquaculture systems, I really request you guys to go ahead and Google it and you can start the research work going on in IIT Kharagpur itself in my lab and also you can go ahead with the different work going on in all over the world.

So, it is very high end technology now people are working on and this is the future the food production I would say in general.

What are the challenges that are there in case of smart Aquaponics systems the excessive accumulation of dissolved nitrogen, nitrate in the reused water because sometimes the nitrate gets it is still be there with time it can get passed through this hydroponic life and because the it can lead to the overstimulation and the mutation of the cultured aquatic organisms that has to be taken care of.

In the conventional aquaponic systems water losses due to the evaporation is only around 1.5 percent while for smart aquaponic systems it can be a little bit higher, because you use different small device sensors and all which produce heat and energy. However, they can be minimized if you have a proper air conditioning unit and proper system air conditioning which will provide and reduce in the water consumption in general.

As the same water recirculates between the bed and the fish tank does the chances of system contamination increases as one's contaminated the infestation spreads rapidly but you can control it.

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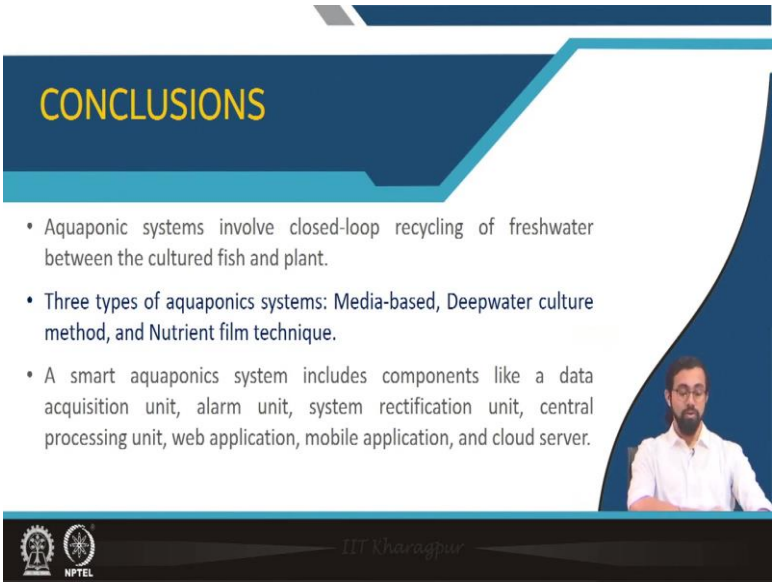

Actually this is controllable if you put proper effort in your system, you can definitely control it you can minimize the any damage to your system. So, in conclusion what we learned from this smart Aquaponics systems, first of all, this Aquaponics system we know it is a closed loop recycling of fresh water between the cultured fish and a plant, 3 types of aquaponic

systems we discussed media based, deep water culture and nutrient film technique or NFT in short.

Smart aquaponic systems we discuss about the components that it has like in general the data acquisition unit, alarm unit, system rectification unit, central processing unit, wave application, mobile application and cloud server.

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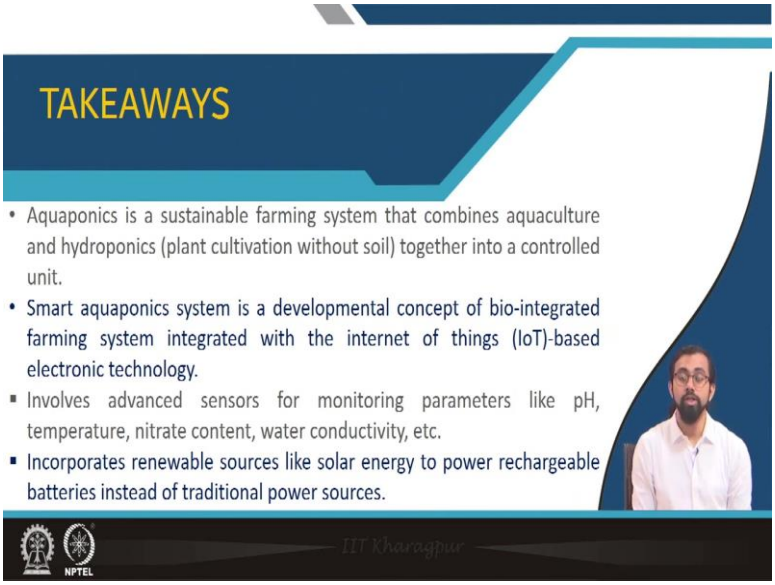

So, the major takeaway from this lecture, I am pretty sure that you get to know some very high knowledge about these smart aquaponic systems and you can I will be very happy to help you with the further development of knowledge on this particular sector. In general, this is a sustainable farming system that combines aquaculture with hydroponics which is like, like culture of plant cultivation of plant without the presence of soil together into a control unit.

Smart aquaculture Aquaponics systems is a development concept in a bio integrated farming system integrated with Internet of Things based electronic technology, it involves the adverse sensors for monitoring parameters like pH, temperature, nitrate, water conductivity, ammonia, et cetera it incorporates renewable sources of energy like solar energy to power rechargeable batteries, instead of traditional power.

So, the same way as we discussed in the last lecture also if you remember we can utilize the geothermal energies and all to reduce or the some structural modification in ~~the~~ Poly houses

to reduce the load in your refrigeration unit and we can make it green refrigeration unit as well.

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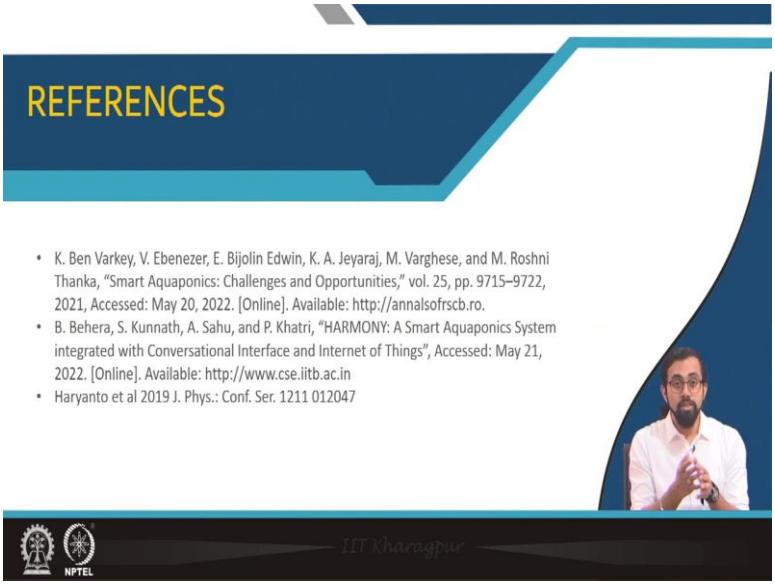

So, these are the references that we can follow to know more details more information about this technology and how what is it all about. So, I hope this lecture is, was really give you some very basic, some like overall details about aquaponic systems and how the smart aquaponic system works. I hope you can utilize this knowledge and you can develop your own entrepreneurial or research goal in this field in future. Thank you so much. See you in the next lecture.