Advanced Aquaculture Technology
Professor Gaurav Dhar Bhowmick
Department of Agriculture and Food Engineering
Indian Institute of Technology, Kharagpur
Lecture 28
Feed Formulation – Linear Programming

Hello everyone, welcome to the third lecture of the modules aquafeed technology. So my name is Professor Gourav Dhar Bhowmick, I am from the Agriculture and Food Engineering department of Indian Institute of Technology, Kharagpur.

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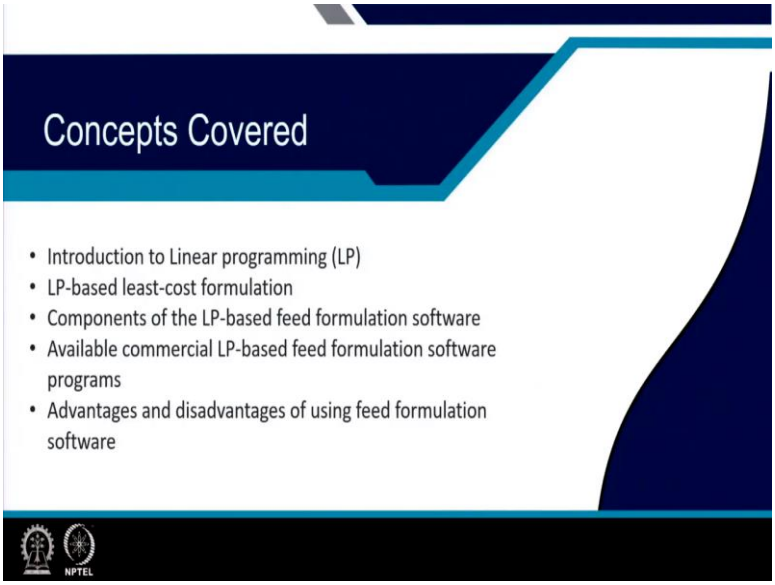

In this lecture module will be discussing about the concepts like introduction to the linear programming as you already remember in the last lecture we discussed about different feed formulation methods. The first one we discussed already pearson box method, so in this lecture method will be discussing about the linear programming method.

How linear programming based least cost formulation is calculated and what are the components of this LP based feed formulation software. And what are the available commercial LP based software for feed formulation process and what is the advantages and disadvantages of them.

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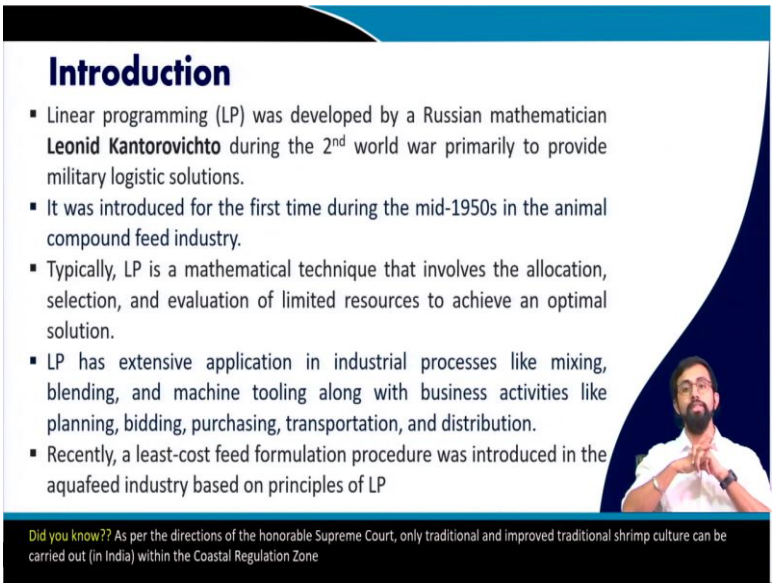

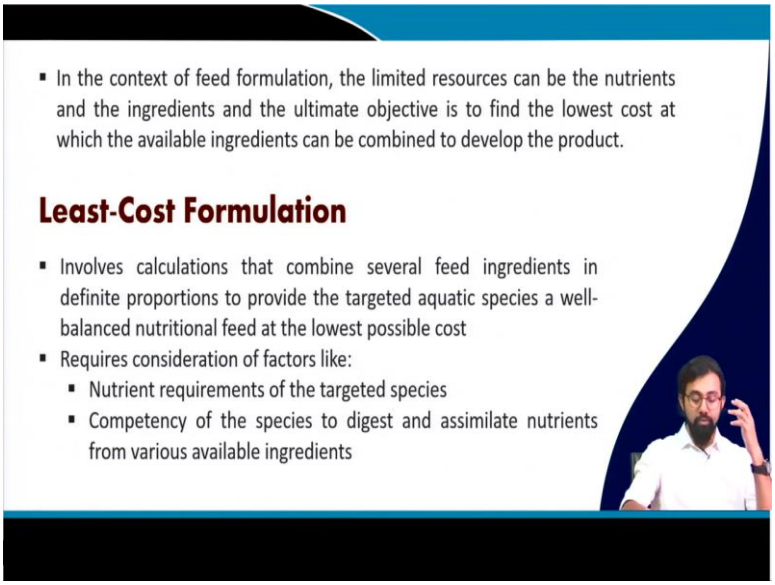

So in general, linear programming was developed by the Russian mathematician Leonid Kantorovichto, so he first formulated or developed this linear programming method during the second world war and which primarily to provide the military logistics solutions and frankly speaking this world war in this crisis situation only the the maximum of the scientific development takes place in human history, this is one of the examples.

This linear programming it was introduced in the first time during the mid 1950s for the animal compound field industry as well and this technique now involves the allocation, selection and evolution of the limited resources to achieve an optimal solution. So linear programming has extensive application in the industrial process like mixing, blending

machine tooling along with the business activities like planning, bidding, purchasing, transportation and a distribution network and all these things developed.

Recently a least cost food formulation procedure was introduced in the aquafeed industry based on the principles of linear programming. In the context of feed formulation like the limited resource that can be the nutrients and the ingredients and ultimate objective is to find out the lowest cost at which the available ingredients can be combined to develop the product.

So first one let us discuss about the least cost formulation, from the name itself you can understand that what we are targeting here; we are targeting the nutrients which are essential for development of your product, however, you are searching for the least cost method by which you just optimize the ample amount of supplements that is the nutrients that is required by getting it done by using the raw materials which are cheap in cost.

It can be costly raw materials as well but you have to optimize, use it very optimally so that is what we are doing here. For that you have to use the linear programming method otherwise it is very difficult for normal human calculation process. So linear programming is the process by which we can easily calculate, we can formulate the required feed for our reared aquatic species.

It involves with the calculation of several food ingredients in definite proportions to provide the targeted aquatic species, a well-balanced nutritional food at a lowest possible cost as we discussed. So required consideration of factors like first nutrient requirements of the targeted species that you need to remember that you need to jot it down first, second competency of the species to digest and assimilate the nutrients from various available ingredients.

So suppose as we discussed in the last lecture about the pearson box method remember we use rice brans and ground nut oils and also, we use this ingredient which already has the nutrients which is required but at which percentage we need to use them; that is the matter of concern. That is where the linear programming comes into the picture and then we start doing the least cost formulation methods.

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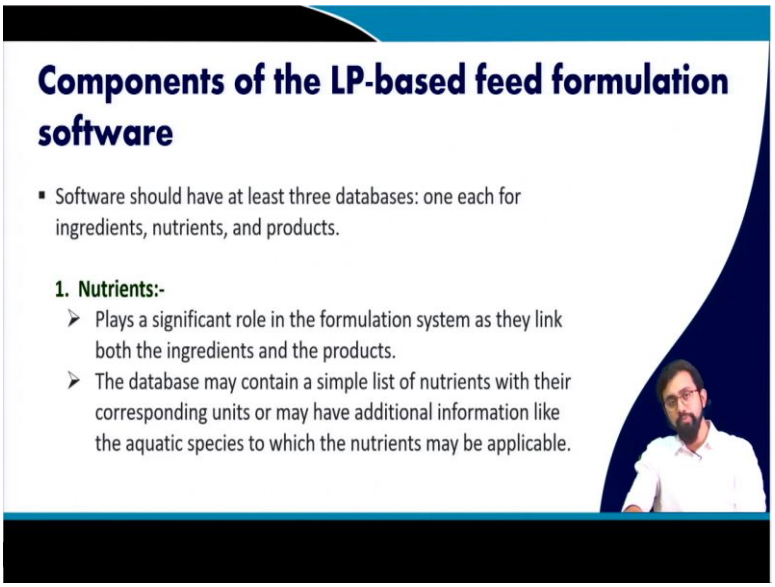

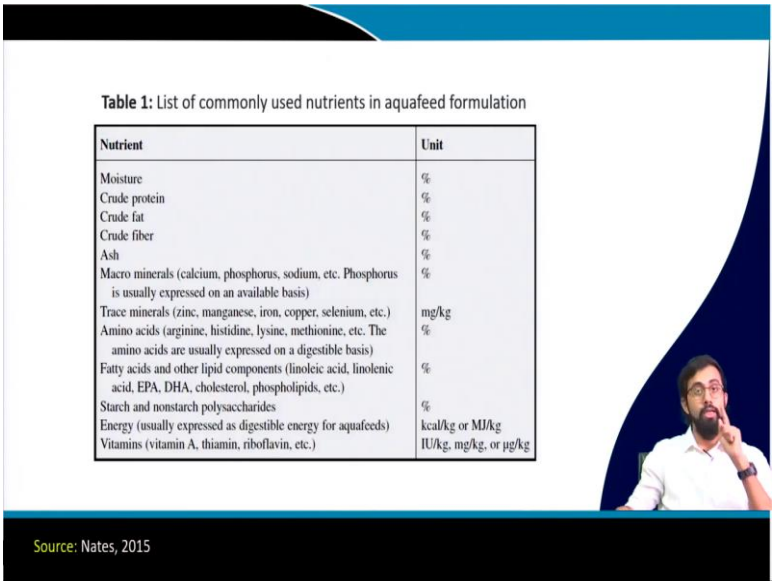

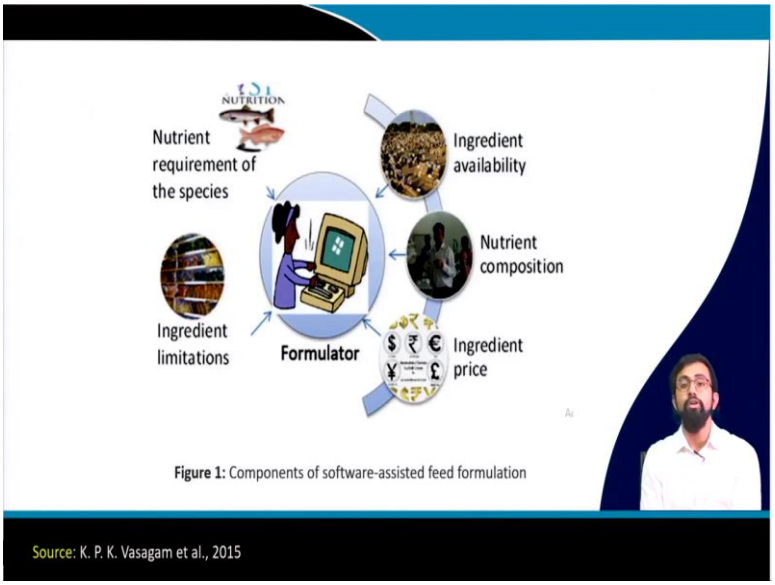

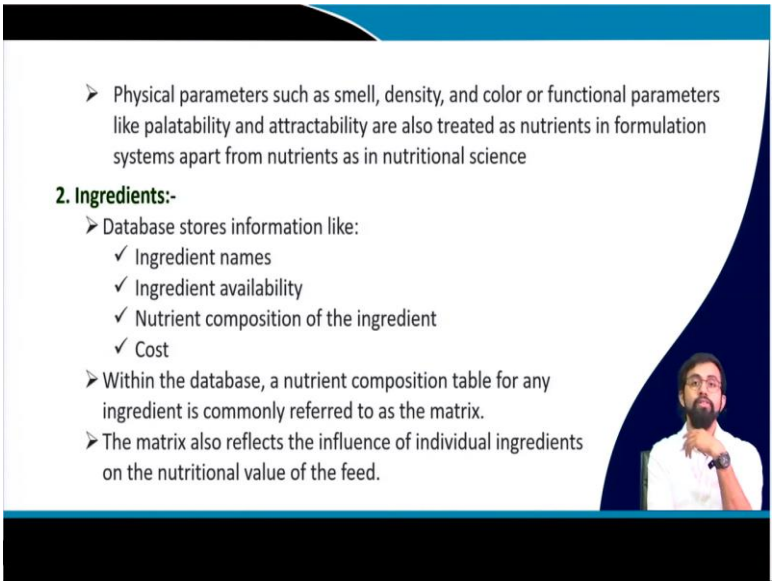

So what are the components that is required when we do the linear programming based feed formulation we use these softwares and all, mainly it use three database. First one is the nutrient, second is the ingredient and third is the products. So what is the nutrient definitely you need to understand, what is the percentage of nutrient or what is the role of it in your target reared species and all, you have to remember all the values.

So that is why nutrient plays a significant role in the formulation system as they link both the ingredients and the product you understand, ingredient here is the raw material, nutrient is the expected outcome or I would say like not outcome better say that expected proportion of nutrient that it requires. Third thing is the product, so raw material process product; so ingredients, nutrient, product.

Nutrient is the major link between the ingredients and the product and it also give the database with the information about the corresponding units and may also have some additional information like the aquatic species to which the nutrients may be available applicable. So what are the list of commonly used nutrients which are available for a aquafeed formulation, what are the information this is given in this table if you see.

What are the information we need to provide; moisture content, crude protein, crude fat, fiber level, ash content, macro minerals like calcium, phosphorus, sodium, etc. Phosphorus is usually expressed in available basis, why I said my macro minerals these are the most essential mineral materials.

It has a higher value, higher amount of macronutrients are required for aquafeed formulations, whereas the trace minerals like zinc, manganese, iron, copper, selenium it needs in a very smaller percentage. Then there comes this amino acids, what type of amino acids you are providing like say it is arginine, histidine, lysine, methionine and like it has to be provided that with the number or the percentage and it is normally expressed in digestible basis.

It is not the amino acid that is available but digestible, you cannot just say like it has this percentage of amino acid, this percentage of lysine is available for that and suppose this lysine is like it is bounded in nature and it is not actually digestible for the purpose of feed formulation, purpose of your larvae or purpose of your target rearing species, so it does not make sense.

So this amino acids are normally expressed in the form of digestible bases, fatty acids and other lipid contents like linoleic acid, linolenic acid, EPA, DHA, cholesterol, phospholipids, etc. Starch and non-starch polysaccharides, energy usually expressed in a digestible energy for aquafeeds, in general it is like kilo calorie per kg or mega joule per kg and vitamins like vitamin A, thiamine, and riboflavin like this is the form of vitamin D and it is normally in the milligram per l kg or microgram per kg something like that.

So these are these different forms of nutrients that we normally require and what are the components of software assisted feed formulation, if you see the formulator, he or she needs information regarding the ingredient availability, what will be the nutrient composition that we require, what is the ingredient price from which the nutrient will be available, what is the

limitation of ingredient or is it really available in your near vicinity like your near market or not and whether it has to be transported from outside.

All these factors nutrient requirement of the species all these factors are very important for the formulator to put the values in the linear programming method and any kind of method can be used and any kind of software is used in using this linear programming method and that will give you the exact feed formulation values.

The physical parameters like smell, density and color and functional parameters like palatability or attractability are also treated as nutrients in formulation systems, apart from the actual nutrients as in nutritional science. Because these are something which is very important you just cannot deny the factor that you prepare a best optimal solution, optimal feed formulation for your system and which smells very bad.

No one going to use it which has a very high intensity, so it will definitely be useful for your floating purpose, anyways I am just giving you an example. It is color it is like functional parameters like palatability whether it is palatable or not, whether it is attractable or not for the fish and all.

There are different factors which actually involves when you design; that is why these parameters are also important and considered as a kind of passive nutrients or passive nutrient requirement when we do the synthesis when we do this calculation in software for this linear programming. What are the ingredients database stores information like ingredient names, availability and nutrition composition of the ingredients and their cost.

So this informations are very important in terms of ingredient, we discuss about the nutrition till now now we discuss about the ingredient. So what is the name of the ingredients from which the nutrient will be taken, it is available in the lower market, it is composition by nutrient composition inside the ingredient just like in the last example in last lecture, the rice bran has 18 point something percentage or 12.8 percentage of crude protein and which is important, this information is needed and what is the cost for it.

You can have source of crude protein and which cost like thousand rupees or ten thousand rupees a kilo, so you definitely not go for it, so these are the informations that you need to have. Within the database a nutrient composition table for any ingredient is commonly known

as the matrix and the matrix always reflects the influence of the individual ingredients on the nutritional value of the final feed.

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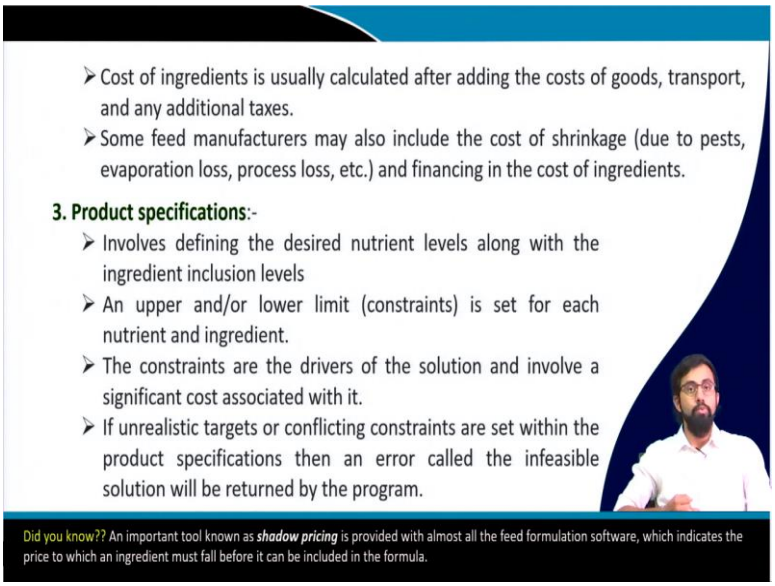

See this is the sample matrix value of example soybean meal, suppose you are preparing a soybean meal for your fish for your reared species which has 46 percent as a protein content, so these are the matrix value of the example soybean meal. What does that mean, dry matter 88 percentage, crude protein 46.3 percentage, crude fat 2.7, crude fiber 4.5.

Digestible energy 3.3150 kilocalorie per kg, calcium 0.35 percentage, digestible lysine, digestible methionine thionine, choline all these values are given. So all this is called the matrix value of all the nutrients available for your final feed formulation. The cost of

ingredients is usually calculated after adding the cost of goods, transports and other additional taxes.

Some feed manufacturer may also include the cost of shrinkage due to the pests, evaporation loss, process loss and the financing in the cost of ingredients. Product specification when we calculate it involves defining the desired nutrient levels along with the ingredient inclusion levels; this is the product that I am talking about. Now nutrient is discussed ingredient is discussed now is the final product.

Final product specification when we discuss about it involves with the defining the desired nutrient level along with the ingredient inclusion level and upper and the lower limit is set for each nutrient and ingredient. The constraints are the drivers of the solutions and involve a significant cost associated with it, what does that mean like suppose you know your final product, you have to know your final product before you discuss anything in a linear programming method or any method you have to know your final product, what is your target.

When you know the target species, in your target feed the crude protein level has to be 25 percent then only you can start discussing about all the other factors; you have to know this factor you have to know this specification, product specification that is very important. So once you know this product specification then you starts calculating the amount of ingredient that it requires because you know the amount of nutrient present in the ingredient itself, you got my point.

So from there we calculate and we do the reverse engineering kind of thing and then we came up with the final amount of ingredients that it requires to get a final value of crude protein of 25 percent in the final product, which is how it is done. So the constraints are the driver of the solutions and involving the significant cost associated with it definitely, if unrealistic target or conflicting constraints are set within the product specification then an error called the infeasible solution will be returned by the program definitely.

If you remember in the last lecture I have given you one problem I have discussed about when we discuss about the Pearson's box method, I have given you some problem just let me know whether it is a infeasible solution or the feasible solution? Your ingredient has 20 percent of crude protein, A a has 20 percent crude protein, B has 10 percent crude protein.

Now I am asking you to develop a final product which is having 50 percent crude protein how are you going to develop it?

I am not allowing you to concentrate anything if I am simply allowing you to only mix it is it possible to go for final product with a 50 percentage of concentrated crude protein only by mixing, no concentration is done, no concentration technique is used, no other manipulation is used, only simply mixing, it is infeasible, that is what we need to discuss that is why we need to understand. Unrealistic target you cannot do it so you cannot come up with the product which is having with unrealistic or the conflicting constraints.

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So this is the example of the product specification of a tilapia grower feed. Now that we know that in order to make a feed for tilapia grower feed you need to have a nutrient available for the feed crude protein level is around minimum 28 percent then you can start discussing about the factors like what are the ingredients that you can use so that your final product should have at least 28 percentage of the crude protein.

Same way fiber concentration should be maximum 4 percentage, you cannot have ingredients which can suppose you mix up a certain ingredients and then you come up with more than 28 percentage of crude protein but it also contains 10 percentage of fiber definitely it is not usable, definitely it is not acceptable for as a tilapia grower feed. Then there comes the computational method then there comes all these linear programming softwares and all where they are useful for us to finalize, optimizes values of the ingredient specifications.

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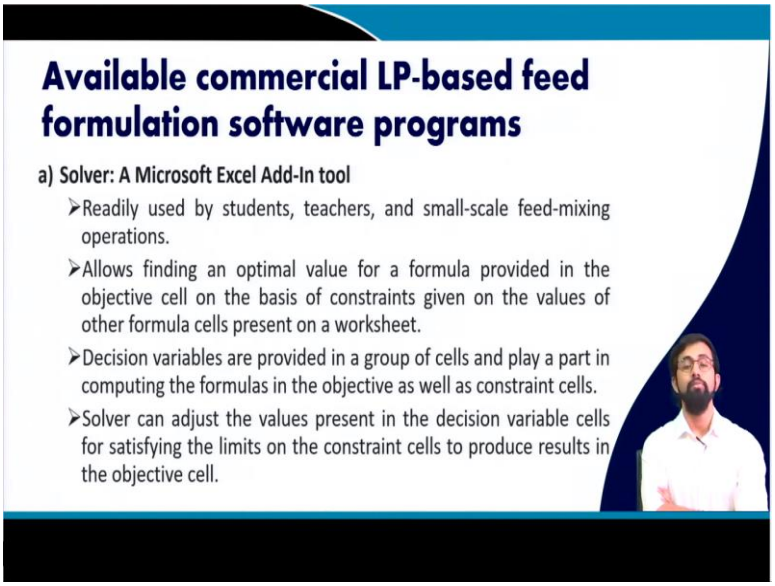

What is the solving mechanism like what are the software programs that is available with this linear programming based feed formulation software those are available I am not going into details there are different linear programming techniques that you can simply google and you can learn from the NPTEL lecture materials only and if you want further discussion you can definitely contact with me anytime.

And definitely you can or any way in Google is available you just simply search for linear programming methods you can got to know a lot of lecture material available on this particular sector and you get to know more in detail in depth knowledge. So just because in this lecture maintain I do not want to go in detail discussion of all these methods because the time constraint.

So I will only discuss about the software packages those are available for this feed formulation method. We have a method called solver, we have a software called solver a microsoft excel add-in tool that is available that you can simply use it and it is famously used by the students, teachers and feed mixing operators and all. It can adjust the values present in desirable variable cells for satisfying the limit of the constraints cell and to produce the results in the objective cells in absolute manner.

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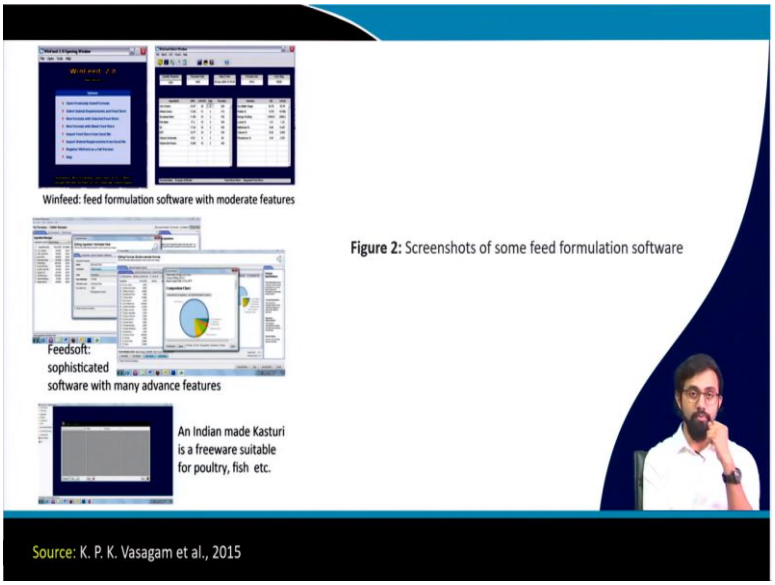

There is another software that is Winfeed it is an inexpensive software package it provides easy to operate user interfaces to manage the feed formulation for teachers and small scale feed mixing problems. Another software Feedsoft which also provide the user friendly interface, multiple clients and plants and like cloud services can be managed simultaneously to provide professional tools for a consultant and the small scale feed companies.

Other than that Adifo they have this Bestmix software, feed management system from the Brill software, Format international from Format software, A systems from Aliix2 software. These are certain softwares and which are available sometimes in packages and sometimes even in free learning methods also, so this you can use along with accuring knowledge more

about the linear programming how it actually been done in mathematical way and then you go ahead with this using these packages that will give you more in-depth idea about how actually feed formulation has been taking place and how it is to be done.

These are the some screenshot of the some feed formulation software Winfeed, Feedsoft and there is a Indian made Kasturi is a freeware available which is suitable for poultry and feed formulations and all know so that also you can use. All these data are available from the Vasagam et al 2015, I will share you the reference so that you can go google it and you can learn from the paper itself, the report itself so what the softwares are and how it works and what are the information that you need to know before you run these softwares.

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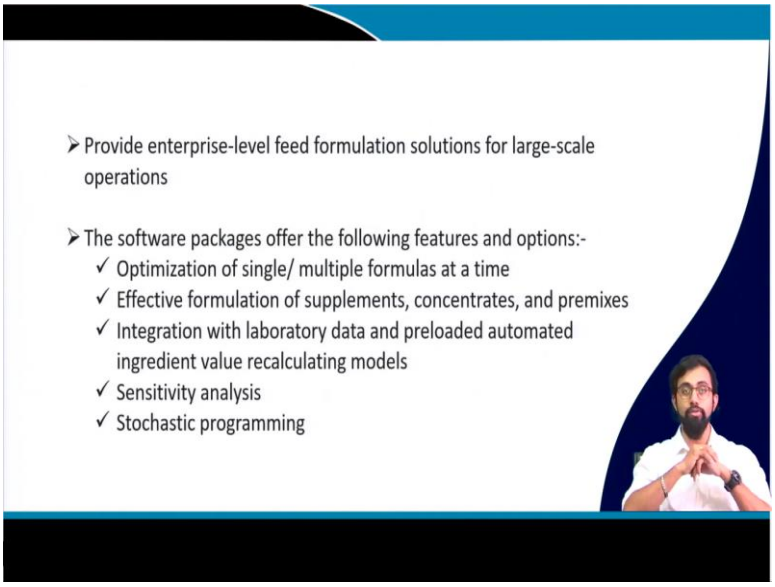

In general, this all this enterprise level feed formulation solutions can be provided by using these softwares for large scale operations. The software packages offer of for optimization of any one single and multiple formulas at a single time, it can give you the effective formulation of supplements, concentrate, and the premixes. Integration with laboratory data and the pre-loaded automated ingredient value recalculating models is possible.

Sensitivity analysis you can do that, how much of a stochastic programming like this is a stochastic programming method. So in general this software packages has all the necessary requirement available for you to do a single-handed practice on feed formulation for your target aquatic species or reared aquatic species.

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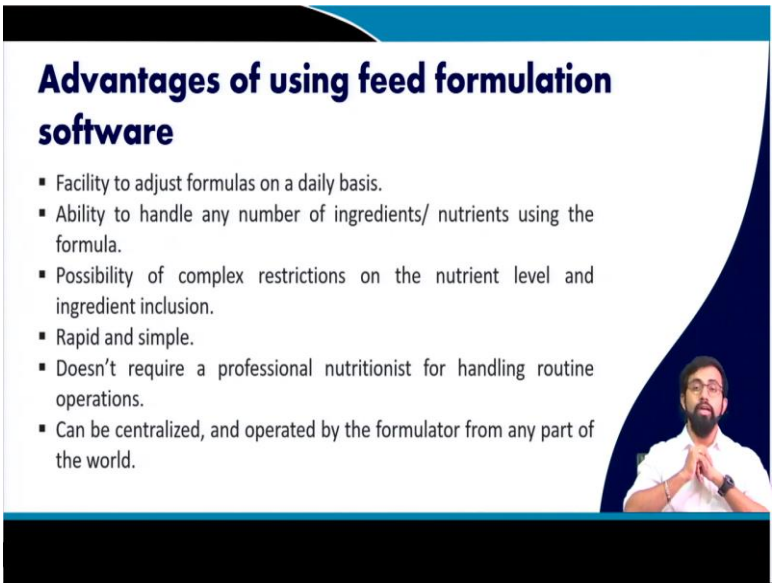

What are the advantages of these softwares; the facility to adjust formulas on a daily basis, ability to handle any number of ingredients or nutrients using the formula, possibility to do the complex restriction on the nutrient level and ingredient inclusion, rapid and it is very simple, does not require a professional nutritionist for handling the routine operations, it can be centralized and operated by the formulator from any part of the world and he can provide you with the data or information.

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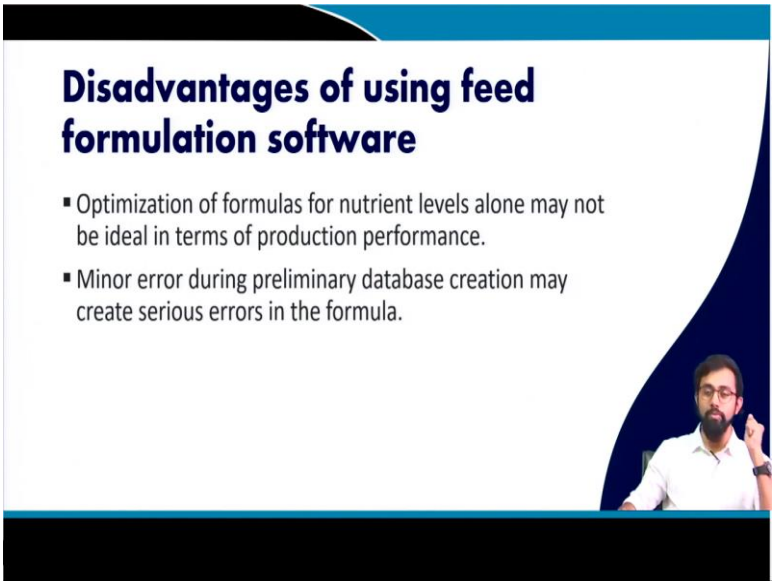

What are the disadvantages, optimization of the formula for nutrient levels alone may not be ideal in terms of production performance, sometimes only on the basis of nutrients when you

optimize these formulas and all sometimes it will not give you the exact, it is like if you do a calculation and proper scientific method and do all this chemical formula and software you put things and then you make a mix up, or like “khichdi” like the famous food normally being eaten by northeast India people and then even in South India always it is available I am not sure about it like how it called there everywhere so in general it is called “khichdi”.

So if you go for proper feed formulation software and all you have to optimize all those things at the end the final product you may not like it that is possible. Though it has all the nutrients possible, it has all the aroma, smell everything but something will not click because we have all the other taste organs with all the all the other sensory organs not everything is like perfect, not everything can be made perfect by only optimizing nothing there must be something that you are left with.

So I am just giving you in terms of very unscientific discussions that I am doing right now but in general scientifically it is doable everything is optimizable but I am saying still there must be something that can be left and must be something that is not formulatable like you can just not use it for your feed formulation, it is not possible sometimes.

Those techniques or those particular type of ingredients or taste or it needs to be, how to say one to one basis you cannot just go ahead with it so there are restrictions on this method as well disadvantages, but though I would not say much of a disadvantage there is a possibility to withstand it or to somehow troubleshoot it. Minor error during the preliminary database can create huge serious error in the whole formula and at the end you will end up with creating nuisance in your farm, because of the providing non appropriate fish feed.

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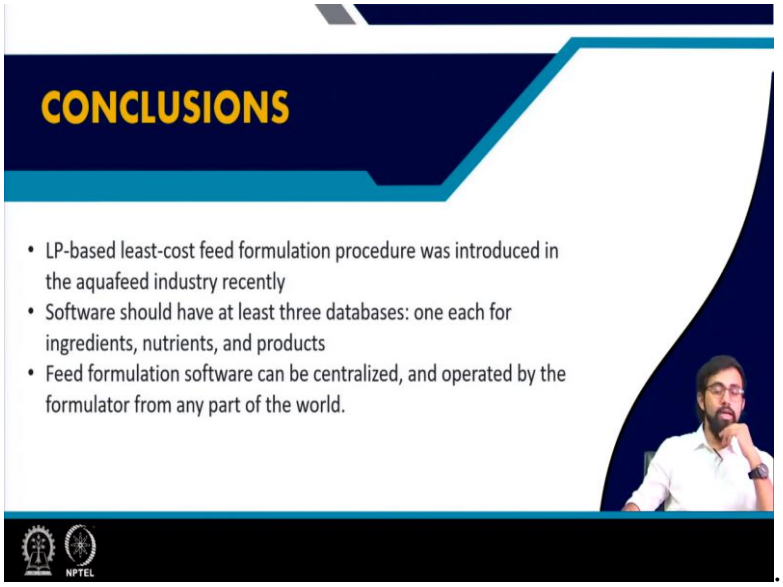

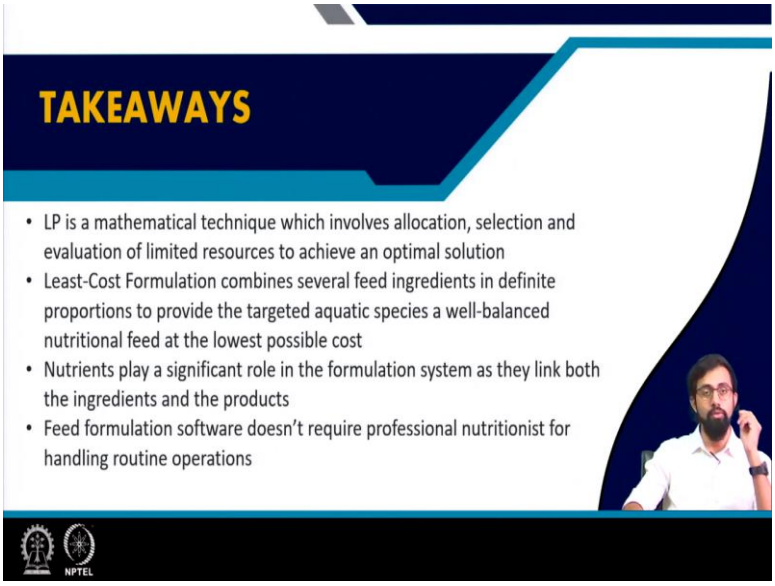

So in this lecture and from the previous lecture we understand the feed formulation, we understand the pearson box method now we understand in this lecture the linear programming methods, why they are used, what are the software packages, how we can understand it better, what is the purpose of using it.

So it was introduced recently in this aqua feed industry, the LP based least cost feed formulation method, softwares are available at least with the three database, one is for ingredients, nutrients and products. Feed formulations software can be centralized which is like the futuristic model that we are talking about. Once it is centralized you do not have to do it each home basis, one centralized feed formulation software is there.

So suppose can be operated by any formulator from any part of the world that is doable and that is why these software packages are becoming very popular and those are normally very much user friendly. It is a in general what is the take away from this lecture, the linear program is a mathematical technique which involves the allocation, selection and evolution of limited resources to achieve an optimal solution or the optimal requirement.

Least cost formulation combines the several feed ingredients in definite proportions to provide the targeted aquatic species a well balanced nutritional feed at the lowest possible cost, and the nutrients plays a significant role in the formulation system as they both link the ingredients as well as the product.

So based on the product requirement, based on the nutrient availability and based on the nutrient available in the ingredient we kind of match these three different resources and we

use it to make up for optimal solution, we need to make it for optimal resource final feed formulation.

Feed formulation software does not require the professional nutritionist in general, that is the best thing about it and it can be centralized and formulator can be from any place in the world and they can utilize the software and they can use it for their purposes, so this is the future of feed formulation and these techniques people are working on it since scientists are working on more advanced techniques like advanced software packages and all.

These are the references from which I have taken some informations you can click the picture you can just google this material, you will get to know a lot of information from it. So thank you so much that is it for this lecture material, we will see you in the next lecture thank you so much.