Advanced Aquaculture Technology
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Lecture 27
Balanced Diet and Feed Formulation

Hello everyone, welcome to the second lecture of the module six balanced diet and the feed formulation. My name is Professor Gourav Dhar Bhowmick from the Agriculture and Food engineering department of Indian Institute of Technology, Kharagpur.

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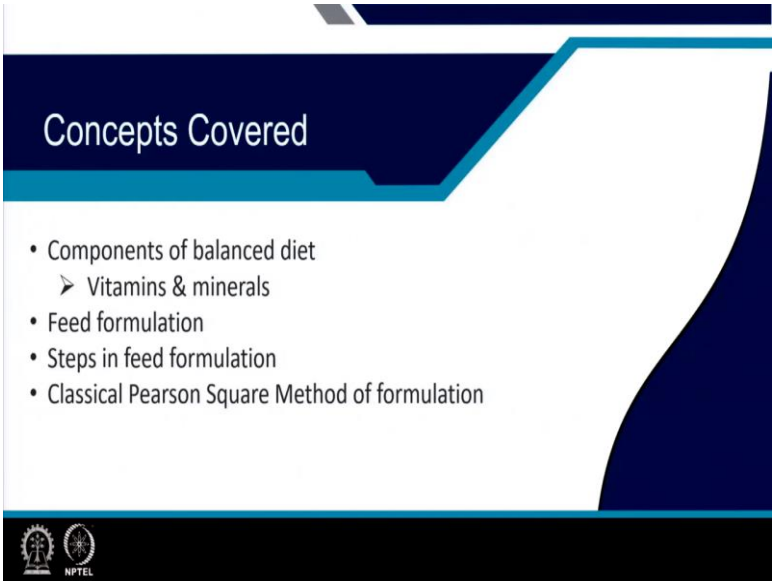

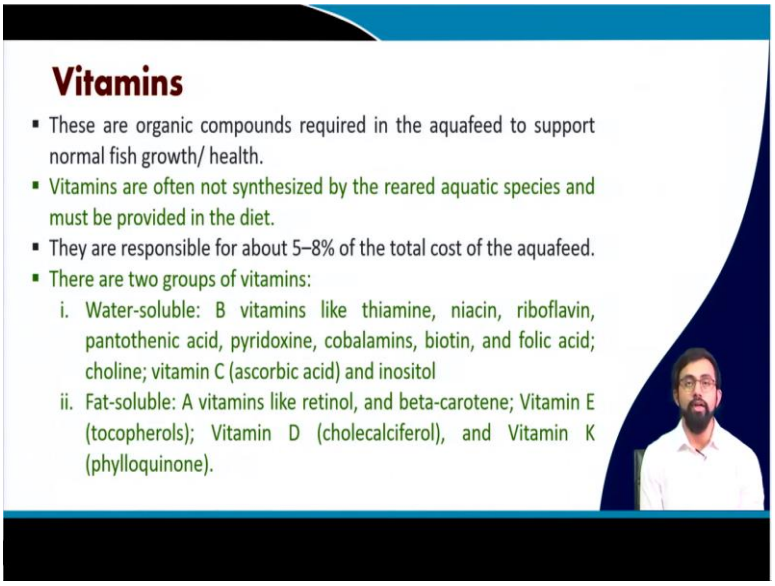

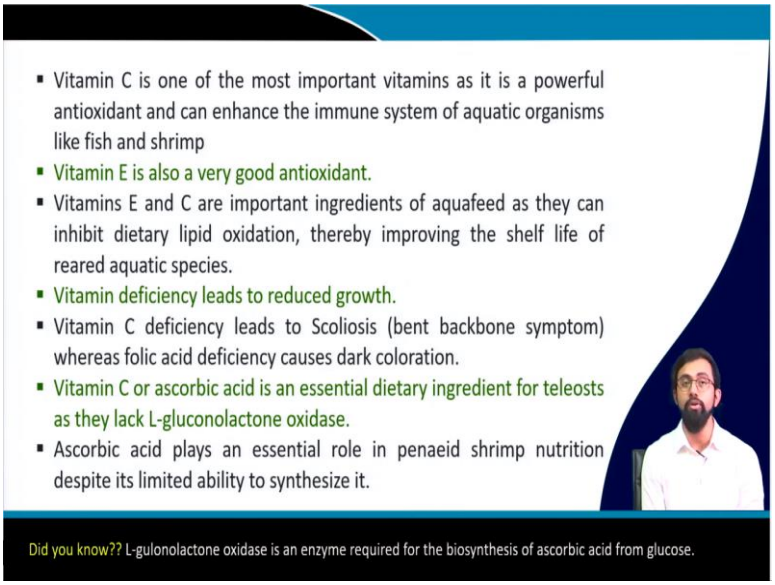

In this particular lecture I will be covering the concepts like the components of balanced diet, I mean we have already covered the discussion about the protein, lipid and carbohydrate content; so today I will be continuing the lecture along with the discussion with the vitamins and the minerals requisites for the feed formulation.

Then we will discuss about what is feed formulation, how we do that and what are the steps involved with it and how are standard methods available for the feed formulation. We will be discussing about the classical Pearson Square method in this particular lecture. As we know that the vitamin are an organic compound which are required to be in the aqua feed to support the fish growth and the health.

So it is almost like the same way we did we need those vitamins in our body some are essential ones like which really we want to have it in our system along with the food that we normally fed with. So it is the same for fish as well for any aquatic species as well. In general vitamins are not actually synthesized by the reared aquatic species and that is why we need to provide them with the diet or the dietary supplements.

In general this actually constitutes around 5 to 8 percent of the total cost of the aqua feed however, those are essential. In general there are like two groups of vitamins like for even human consumption also we know these two types of vitamins first is water soluble, second one is fat soluble. What are the water soluble vitamins; like vitamin B mainly like thymine, niacin, riboflavin, pantothenic acid, pyridoxine, cobalamin, biotin and folic acid and also vitamin C like ascorbic acid and the inositol.

So these are the one which are in general water soluble vitamin. So what are the fat soluble vitamins? Vitamin A like the retinols, beta-carotene, vitamin E like tocopherols, vitamin D cholecalciferol, then vitamin K that is phyloquinone. So these are the ones which are fat soluble vitamin. So these are very important information that we need to remember.

And vitamin C which is one of the most important vitamin that has a powerful antioxidant capacity and because of that it can enhance the immune system of aquatic organisms like fish and shrimp. Vitamin E is also very good antioxidant; vitamin E and C are important ingredients in the aqua feed because they can inhibit the dietary lipid oxidation, thereby improving the shelf life of the aquatic species.

Vitamin deficiency can lead to reduced growth condition; also they can highly disrupt the health condition of the target aquatic species or the reared quatic species. Vitamin C deficiency it leads to the scoliosis or bent backbone syndrome we call it so whereas the folic acid deficiency causes the dark coloration and all. So these are the symptoms by which you can identify that your target aquatic species or rearing species is infected or like having some vitamin C deficiency or like some vitamin deficiency syndrome.

In general the ascorbic acid or like vitamin C is an essential dietary ingredients for teleosts waste as they lack the L-gluconolactone oxidase and what is this teleosts like most of them almost like fifty percent of the fin fish are actually called teleost all the salmon species and all these things, so in general the ascorbic acid plays an essential role in penaeid shrimp nutrition despite its limited ability to synthesize it.

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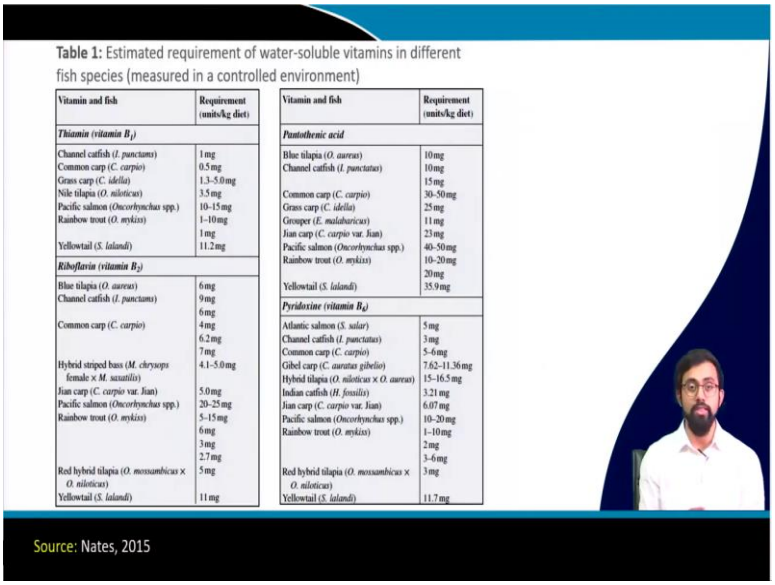


Table 1: Estimated requirement of water-soluble vitamins in different fish species (measured in a controlled environment)

Vitamin and fish	Requirement (units/kg diet)
Thiamin (vitamin B_1)	
Channel catfish (*I. punctatus*)	1 mg
Common carp (*C. carpio*)	0.5 mg
Grass carp (*C. idella*)	1.3–5.0 mg
Nile tilapia (*O. niloticus*)	3.5 mg
Pacific salmon (*Oncorhynchus* spp.)	10–15 mg
Rainbow trout (*O. mykiss*)	1–10 mg
	1 mg
Yellowtail (*S. lalandi*)	11.2 mg
Riboflavin (vitamin B_2)	
Blue tilapia (*O. aureus*)	6 mg
Channel catfish (*I. punctatus*)	9 mg
	6 mg
Common carp (*C. carpio*)	4 mg
	6.2 mg
	7 mg
Hybrid striped bass (*M. chrysops* female × *M. saxatilis*)	4.1–5.0 mg
Jian carp (*C. carpio* var. Jian)	5.0 mg
Pacific salmon (*Oncorhynchus* spp.)	20–25 mg
Rainbow trout (*O. mykiss*)	5–15 mg
	6 mg
	3 mg
	2.7 mg
Red hybrid tilapia (*O. mossambicus* × *O. niloticus*)	5 mg
Yellowtail (*S. lalandi*)	11 mg

Vitamin and fish	Requirement (units/kg diet)
Pantothenic acid	
Blue tilapia (*O. aureus*)	10 mg
Channel catfish (*I. punctatus*)	10 mg
	15 mg
Common carp (*C. carpio*)	30–50 mg
Grass carp (*C. idella*)	25 mg
Grouper (*E. malabaricus*)	11 mg
Jian carp (*C. carpio* var. Jian)	23 mg
Pacific salmon (*Oncorhynchus* spp.)	40–50 mg
Rainbow trout (*O. mykiss*)	10–20 mg
	20 mg
Yellowtail (*S. lalandi*)	35.9 mg
Pyridoxine (vitamin B_6)	
Atlantic salmon (*S. salar*)	5 mg
Channel catfish (*I. punctatus*)	3 mg
Common carp (*C. carpio*)	5–6 mg
Gibel carp (*C. auratus gibelio*)	7.62–11.36 mg
Hybrid tilapia (*O. niloticus* × *O. aureus*)	15–16.5 mg
Indian catfish (*H. fossilis*)	3.21 mg
Jian carp (*C. carpio* var. Jian)	6.07 mg
Pacific salmon (*Oncorhynchus* spp.)	10–20 mg
Rainbow trout (*O. mykiss*)	1–10 mg
	2 mg
	3–6 mg
Red hybrid tilapia (*O. mossambicus* × *O. niloticus*)	3 mg
Yellowtail (*S. lalandi*)	11.7 mg

Source: Nates, 2015

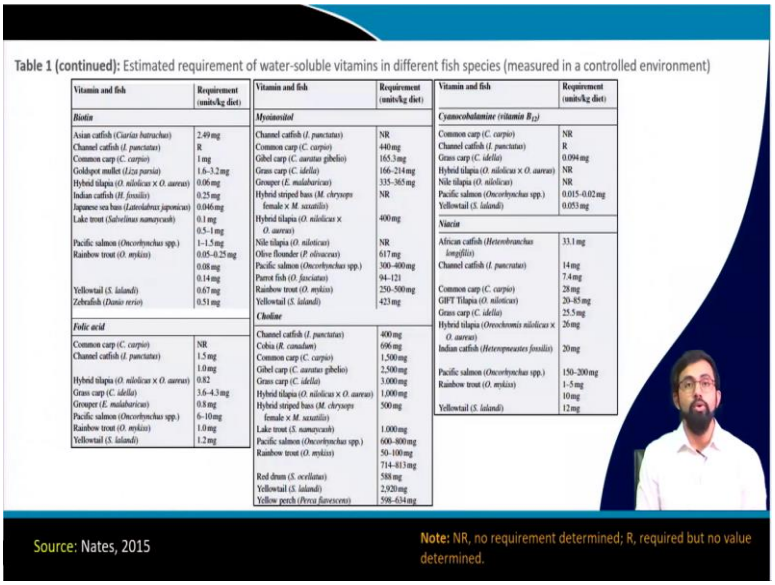


Table 1 (continued): Estimated requirement of water-soluble vitamins in different fish species (measured in a controlled environment)

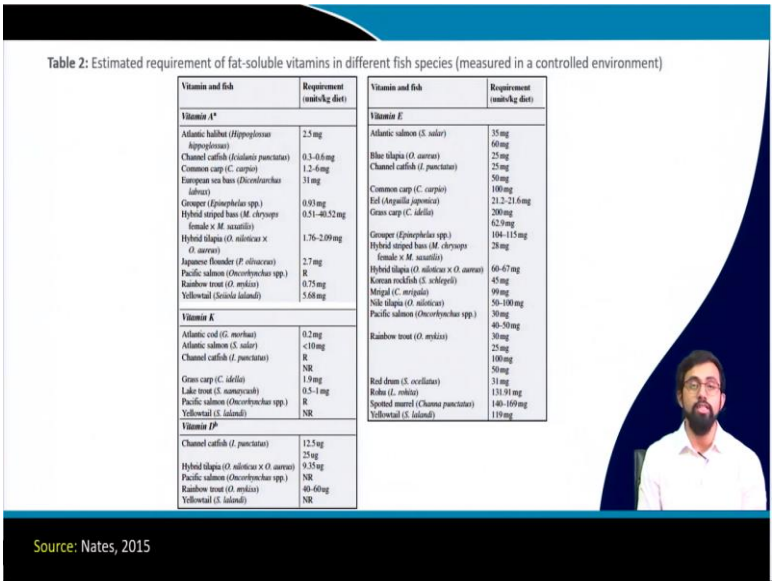
Vitamin and fish	Requirement (units/kg diet)
Biotin	
Asian catfish (*Clarias batrachus*)	2.49 mg
Channel catfish (*I. punctatus*)	R
Common carp (*C. carpio*)	1 mg
Goldspot mullet (*Liza parsia*)	1.6–3.2 mg
Hybrid tilapia (*O. niloticus* × *O. aureus*)	0.06 mg
Indian catfish (*H. fossilis*)	0.25 mg
Japanese sea bass (*Lateolabrax japonicus*)	0.046 mg
Lake trout (*Salvelinus namaycush*)	0.1 mg
	0.5–1 mg
Pacific salmon (*Oncorhynchus* spp.)	1–1.5 mg
Rainbow trout (*O. mykiss*)	0.05–0.25 mg
	0.08 mg
	0.14 mg
Yellowtail (*S. lalandi*)	0.67 mg
Zebrafish (*Danio rerio*)	0.51 mg
Folic acid	
Common carp (*C. carpio*)	NR
Channel catfish (*I. punctatus*)	1.5 mg
	1.0 mg
Hybrid tilapia (*O. niloticus* × *O. aureus*)	0.82
Grass carp (*C. idella*)	3.6–4.3 mg
Grouper (*E. malabaricus*)	0.8 mg
Pacific salmon (*Oncorhynchus* spp.)	6–10 mg
Rainbow trout (*O. mykiss*)	1.0 mg
Yellowtail (*S. lalandi*)	1.2 mg

Vitamin and fish	Requirement (units/kg diet)
Myoinositol	
Channel catfish (*I. punctatus*)	NR
Common carp (*C. carpio*)	440 mg
Gibel carp (*C. auratus gibelio*)	165.3 mg
Grass carp (*C. idella*)	166–214 mg
Grouper (*E. malabaricus*)	335–365 mg
Hybrid striped bass (*M. chrysops* female × *M. saxatilis*)	NR
Hybrid tilapia (*O. niloticus* × *O. aureus*)	400 mg
Nile tilapia (*O. niloticus*)	NR
Olive flounder (*P. olivaceus*)	617 mg
Pacific salmon (*Oncorhynchus* spp.)	300–400 mg
Parrot fish (*O. fasciatus*)	94–121
Rainbow trout (*O. mykiss*)	250–500 mg
Yellowtail (*S. lalandi*)	423 mg
Choline	
Channel catfish (*I. punctatus*)	400 mg
Cobia (*R. canadum*)	696 mg
Common carp (*C. carpio*)	1,500 mg
Gibel carp (*C. auratus gibelio*)	2,500 mg
Grass carp (*C. idella*)	3,000 mg
Hybrid tilapia (*O. niloticus* × *O. aureus*)	1,000 mg
Hybrid striped bass (*M. chrysops* female × *M. saxatilis*)	500 mg
Lake trout (*S. namaycush*)	1,000 mg
Pacific salmon (*Oncorhynchus* spp.)	600–800 mg
Rainbow trout (*O. mykiss*)	50–100 mg
	714–813 mg
Red drum (*S. ocellatus*)	588 mg
Yellowtail (*S. lalandi*)	2,920 mg
Yellow perch (*Perca flavescens*)	598–634 mg

Vitamin and fish	Requirement (units/kg diet)
Cyanocobalamine (vitamin B_{12})	
Common carp (*C. carpio*)	NR
Channel catfish (*I. punctatus*)	R
Grass carp (*C. idella*)	0.094 mg
Hybrid tilapia (*O. niloticus* × *O. aureus*)	NR
Nile tilapia (*O. niloticus*)	NR
Pacific salmon (*Oncorhynchus* spp.)	0.015–0.02 mg
Yellowtail (*S. lalandi*)	0.053 mg
Niacin	
African catfish (*Heterobranchus longifilis*)	33.1 mg
Channel catfish (*I. punctatus*)	14 mg
	7.4 mg
Common carp (*C. carpio*)	28 mg
GIFT Tilapia (*O. niloticus*)	20–45 mg
Grass carp (*C. idella*)	25.5 mg
Hybrid tilapia (*Oreochromis niloticus* × *O. aureus*)	26 mg
Indian catfish (*Heteropneustes fossilis*)	20 mg
Pacific salmon (*Oncorhynchus* spp.)	150–200 mg
Rainbow trout (*O. mykiss*)	1–5 mg
	10 mg
Yellowtail (*S. lalandi*)	12 mg

Source: Nates, 2015

Note: NR, no requirement determined; R, required but no value determined.



Vitamin and fish	Requirement (units/kg diet)
*Vitamin A**	
Atlantic halibut (*Hippoglossus hippoglossus*)	2.5 mg
Channel catfish (*Ictalurus punctatus*)	0.3–0.6 mg
Common carp (*C. carpio*)	1.2–6 mg
European sea bass (*Dicentrarchus labrax*)	31 mg
Grouper (*Epinephelus* spp.)	0.93 mg
Hybrid striped bass (*M. chrysops* female × *M. saxatilis*)	0.51–40.52 mg
Hybrid tilapia (*O. niloticus* × *O. aureus*)	1.76–2.09 mg
Japanese flounder (*P. olivaceus*)	2.7 mg
Pacific salmon (*Oncorhynchus* spp.)	R
Rainbow trout (*O. mykiss*)	0.75 mg
Yellowtail (*Seriola lalandi*)	5.68 mg
Vitamin K	
Atlantic cod (*G. morhua*)	0.2 mg
Atlantic salmon (*S. salar*)	<10 mg
Channel catfish (*I. punctatus*)	R
	NR
Grass carp (*C. idella*)	1.9 mg
Lake trout (*S. namaycush*)	0.5–1 mg
Pacific salmon (*Oncorhynchus* spp.)	R
Yellowtail (*S. lalandi*)	NR
*Vitamin D**	
Channel catfish (*I. punctatus*)	12.5 ug
	25 ug
Hybrid tilapia (*O. niloticus* x *O. aureus*)	9.35 ug
Pacific salmon (*Oncorhynchus* spp.)	NR
Rainbow trout (*O. mykiss*)	40–60 ug
Yellowtail (*S. lalandi*)	NR

Vitamin and fish	Requirement (units/kg diet)
Vitamin E	
Atlantic salmon (*S. salar*)	35 mg
	60 mg
Blue tilapia (*O. aureus*)	25 mg
Channel catfish (*I. punctatus*)	25 mg
	50 mg
Common carp (*C. carpio*)	100 mg
Eel (*Anguilla japonica*)	21.2–21.6 mg
Grass carp (*C. idella*)	200 mg
	62.9 mg
Grouper (*Epinephelus* spp.)	104–115 mg
Hybrid striped bass (*M. chrysops* female × *M. saxatilis*)	28 mg
Hybrid tilapia (*O. niloticus* × *O. aureus*)	60–67 mg
Korean rockfish (*S. schlegeli*)	45 mg
Mrigal (*C. mrigala*)	99 mg
Nile tilapia (*O. niloticus*)	50–100 mg
Pacific salmon (*Oncorhynchus* spp.)	30 mg
	40–50 mg
Rainbow trout (*O. mykiss*)	30 mg
	25 mg
	100 mg
	50 mg
Red drum (*S. ocellatus*)	31 mg
Rohu (*L. rohita*)	131.91 mg
Spotted murrel (*Channa punctatus*)	140–169 mg
Yellowtail (*S. lalandi*)	119 mg

So this is all the very generic discussion that we are having where I have discussed about, I am discussing about the importance of vitamins for the fish growth and the health. The estimated requirement for the water soluble vitamins in different fish species are in given in this table 1 you can take a snap of it and to whenever you will be culturing any specific type of vitamin, specific type of culture species you have to remember like what is the amount of vitamin B1, vitamin B2 like riboflavin or like thymine is required or pantothenic acid like pyridoxine are required for your target aquatic species.

So we normally provide it in the unit is like unit in milligram or nanogram in per kg of diet, so suppose you are supplying per kg of dietary supplement or the feed, so in per kg what is the amount in milligram or nanogram or microgram in general is the vitamin that it requires to be supplemented with. So in continuation with it there are some other examples of different other water soluble vitamins like biotin, folic acid, how these different water soluble vitamins are required, what is the amount that it required for different fish species.

Actually these are measured in the control environment just to make sure the values are actually very lab based result and also here you see NR stands for the no requirement determined and R is the required but no value actually determined. The same way we have also in this table 2 mainly the fat soluble vitamins are shown in different fish species like vitamin A, vitamin K, D and E. So how these different types of fat soluble vitamins are needed at which doses for different type of fish are shown in this table.

In this table 3 I have shown estimated vitamin requirement for a range of shrimp species measured in the controlled environment again and if there is a mixture of all the vitamins are given here with the data for tiger shrimp and the freshly pond and the white shrimps majorly and like even Indian white prawn is also given. So for them what is the requirement of this specific vitamin and all, so that is given; these informations are very much needed for us when we will be doing the feed formulation study for our target aquatic species in our farm.

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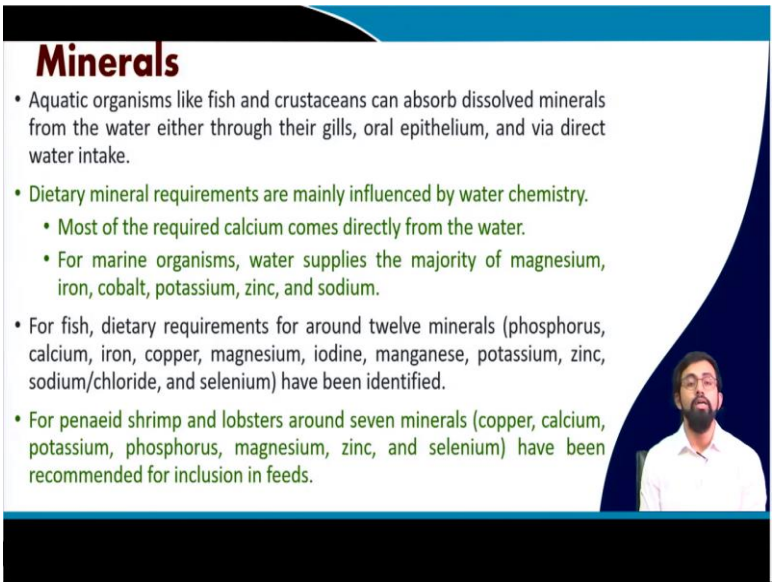

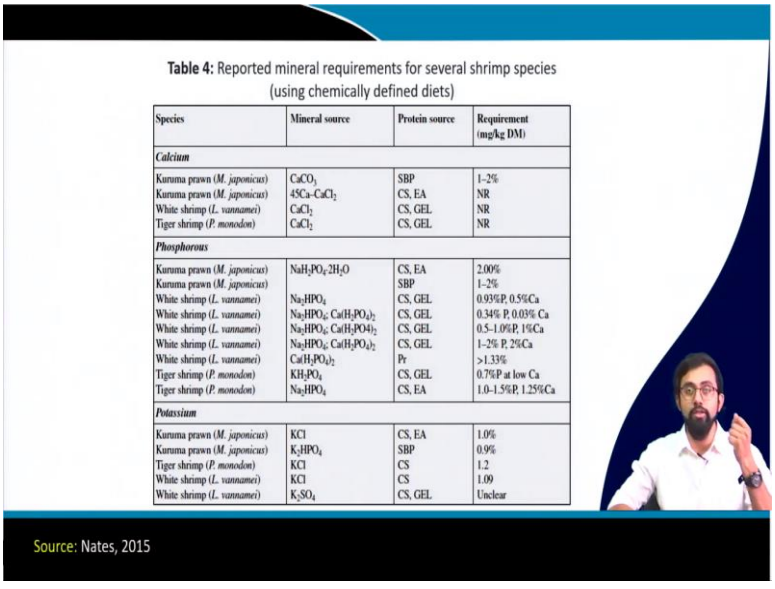

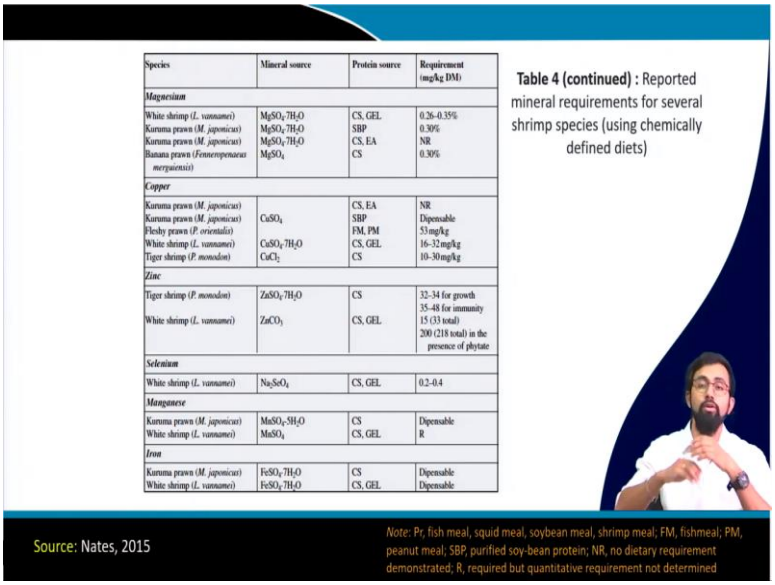

Species	Mineral source	Protein source	Requirement (mg/kg DM)
Magnesium			
White shrimp (*L. vannamei*)	$MgSO_4 \cdot 7H_2O$	CS, GEL	0.26-0.35%
Kuruma prawn (*M. japonicus*)	$MgSO_4 \cdot 7H_2O$	SBP	0.30%
Kuruma prawn (*M. japonicus*)	$MgSO_4 \cdot 7H_2O$	CS, EA	NR
Banana prawn (*Fenneropenaeus merguiensis*)	$MgSO_4$	CS	0.30%
Copper			
Kuruma prawn (*M. japonicus*)		CS, EA	NR
Kuruma prawn (*M. japonicus*)	$CuSO_4$	SBP	Dipensable
Fleshy prawn (*P. orientalis*)		FM, PM	53 mg/kg
White shrimp (*L. vannamei*)	$CuSO_4 \cdot 7H_2O$	CS, GEL	16-32 mg/kg
Tiger shrimp (*P. monodon*)	$CuCl_2$	CS	10-30 mg/kg
Zinc			
Tiger shrimp (*P. monodon*)	$ZnSO_4 \cdot 7H_2O$	CS	32-34 for growth 35-48 for immunity
White shrimp (*L. vannamei*)	$ZnCO_3$	CS, GEL	15 (33 total) 200 (218 total) in the presence of phytate
Selenium			
White shrimp (*L. vannamei*)	Na_2SeO_4	CS, GEL	0.2-0.4
Manganese			
Kuruma prawn (*M. japonicus*)	$MnSO_4 \cdot 5H_2O$	CS	Dipensable
White shrimp (*L. vannamei*)	$MnSO_4$	CS, GEL	R
Iron			
Kuruma prawn (*M. japonicus*)	$FeSO_4 \cdot 7H_2O$	CS	Dipensable
White shrimp (*L. vannamei*)	$FeSO_4 \cdot 7H_2O$	CS, GEL	Dipensable

Table 4 (continued) : Reported mineral requirements for several shrimp species (using chemically defined diets)

Source: Nates, 2015

Note: Pr, fish meal, squid meal, soybean meal, shrimp meal; FM, fishmeal; PM, peanut meal; SBP, purified soy-bean protein; NR, no dietary requirement demonstrated; R, required but quantitative requirement not determined

So next and last important thing is the minerals, so in general the aquatic organisms like fish and the crustaceans what they do, they can absorb the dissolved minerals from the water either through their gills or the oral epithelium or via direct water intake. So these minerals are actually very essential for their health being; so in case of dietary minerals requirement are mainly influenced by the water chemistry.

Suppose in general most of the calcium requirement is already fulfilled by the water, sometimes the marine organisms the water supplies even the majority of the magnesium, iron, cobalt, potassium, zinc and the sodium. So for them this elements are also being supplied by the natural water bodies, so why we need this dietary supplements?

In case of fish there are around 12 minerals which are very important and it is identified to be supplemented with the dietary; like when you will be supplying with a diet or a specific feed so that feed should constitute this different 12 minerals. What are those 12 minerals; phosphorus, calcium, iron, copper, magnesium, iodide, manganese, potassium zinc, sodium or chloride and selenium. So these are the 12 which important minerals for the fishing.

For penaeid shrimp and the lobsters around 7 minerals have been recommended to be included in the feed, which are those seven minerals copper, calcium, magnesium, phosphorus, zinc and selenium. So this copper, calcium, potassium, phosphorus, magnesium, zinc and selenium are the seven important and very recommended by the specialist to be included in the feed material when you will be supplying one will be formulated the feed.

So remember these are very important things we cannot just feed our culture species with anything and everything, you have to be very specific, the feed that you choose it has to constitute all these minerals, all the vitamins required vitamins at a particular doses, all the required lipid, protein and the carbohydrate concentration.

So the reported mineral requirement for several shrimps species are given here like you see it is given in terms of calcium carbonate or calcium chloride, phosphorus, sodium hypophosphate and these things. So sometimes we ho ahead with the potassium also with potassium chloride or potassium sulfate, so anyway this is the sources of the minerals and from which we normally utilize it for at different requirement value that is given in milligram per kg of dry matter.

So it is a continuation of the same table where where there is a report in mineral requirement for several shrimp species usually like the chemically defined diet, so mainly the fish meal, squid meal, soybean meal and the shrimp meals are given here and how they can be supplied with the different mineral constituents are provided in this table.

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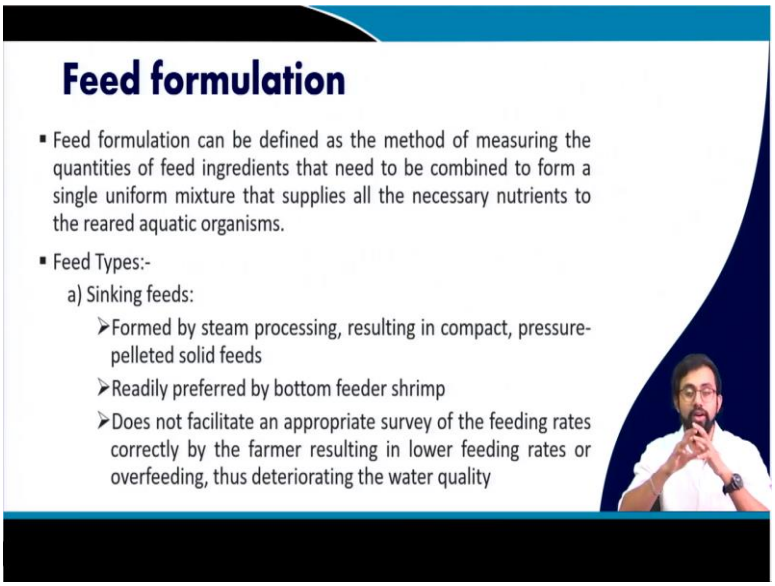

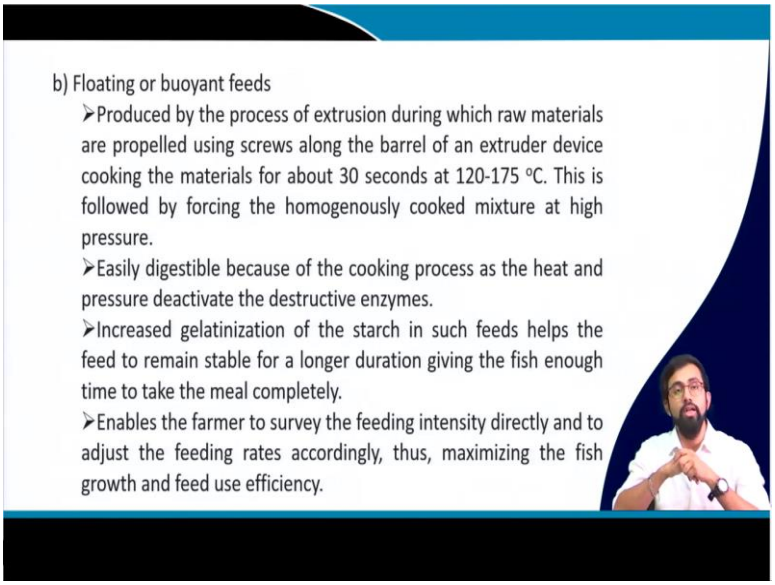

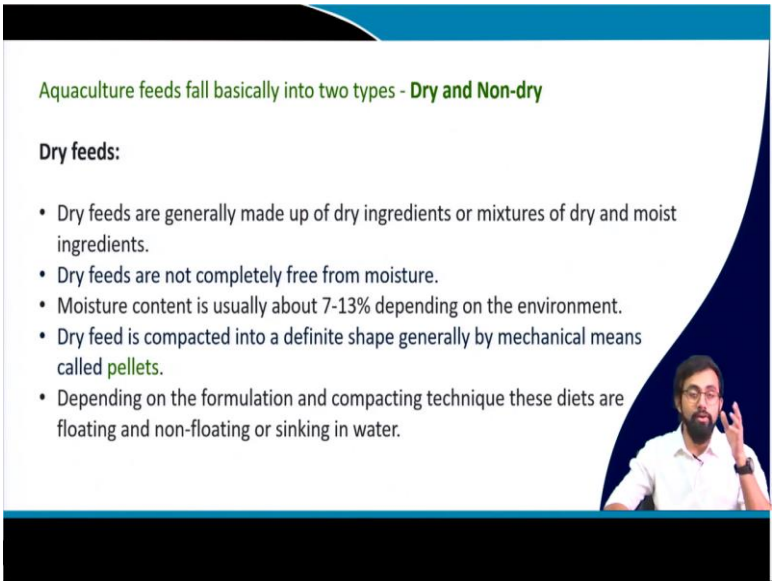

So next final thing that we will be discussing about this in this lecture is about is the feed formulation and will continue this discussion in the coming lectures as well. When we discuss about the feed formulation it can be defined as the method of measuring the quantity of feed ingredient that needs to be combined to form a single uniform mixture that supplies all the necessary nutrients to the reared aquatic organisms.

So it can be of any type of feed but the feed should constitute all the essential nutrient required for your reared aquatic species. So the feed types in general the sinking feed like forms with the shrimps processing resulting in like compact pressure pelleted solid feed so it is readily preferred by the bottom feeder shrimp so it is got sink down in the bottom of your pond or tank and does not facilitate an appropriate survey of the feeding rate correctly by the

farmer resulting in a very lower feeding rate and over feeding and thus deteriorating the water quality.

So this sinking feeds has this demerits or the disadvantages because it got easily sunken in the bottom of the trunk or tank or the river body or the pond body, what will happen you cannot have a proper determination of what is the exact amount of feed that is being utilized and which is actually the feed that is being wasted it is very hard to determine that factor in that case; it is not impossible but it is it is hard in that case.

So the next is the floating or the buoyant feed, so this is the more advantageous when if it is like in a floating condition but it all it also depends like if you are providing a bottom feeder with the floating feed it does not matter, does not make any sense, it is a bottom feeder so you have to provide them with the sinking feed, otherwise the feed they will not come to the top of the surface and coherent with other; mess with other organisms and definitely it will disrupt the whole ecosystem.

So depending on the culture species if it is a polyculture you have to provide them with the floating feed as well as the sunken feed or sinking feed because in that case you may have the bottom feeder as well as the surface feeder or the top feeder. So in general the floating or the buoyant feeds are produced by the process of extrusion during which raw materials are propelled using a screw with a barrel like extrusion device.

So cooking of material is taking place for around 30 seconds at 120 and 175 degree celsius at a very high pressure, that is why it is called high pressure high temperature cooking procedures but by this means the feed that is coming out of the system it is the extruded pallet so the extruded feed. It releases the pressure and because of that it becomes puffy in nature just like we had it in our regular potato thing it is like we you may know what is Kurkure and all so this is actually the type of feed that it looks like.

Almost the same this protein feeds and all because of that the air which is trapped inside the pellets it can easily float in the water bodies. So, increased gelatinization of the starch of this feed of this kind of feeds actually helps the feed to remain stable for longer duration of time and enough time for fish to take the meal completely.

It also enables the farmers to survey the feeding intensity directly and to adjust the feeding rates accordingly and maximizing the fish growth and feed use efficiency because you can

control it, you can see that how much of the feed is actually being left from fish is not being not eating it like or not and based on that you can have even idea about if some unrest or some disease has been broken or there in a farming products or reared species or not.

Because if they are under stress they will definitely eat less and based on that when it is a sunken feed, it is very hard for you to identify like which is the feed and which is the excreta and all this thing, so no difference though like I am just giving an example. So you cannot have a proper say about those things, in case of floating feeds or the buoyant feeds you can have a say about that this much feed is being unutilized so that means definitely your reared species have some issue just go and check them and definitely they are in under stress condition. So this is one of the positive things about the floating feed.

Other than that in general aquatic feeds basically of two types dry and non-dry; dry feeds are normally made up of dry ingredients or mixture of dry or moist ingredients in general, however they are not completely free of moisture. Moisture content can be up to 13 percent depending on the environment but still 13 percent is very less so when you touch it when you feel like it is a very dry one.

Dry feeds are compacted into a definite shape generally by mechanical means and we call them pellet, I will show you how it looks like. Depending on the formulation and the compacted technique these diets can be floating, non-floating and the sinking in water that we already saw.

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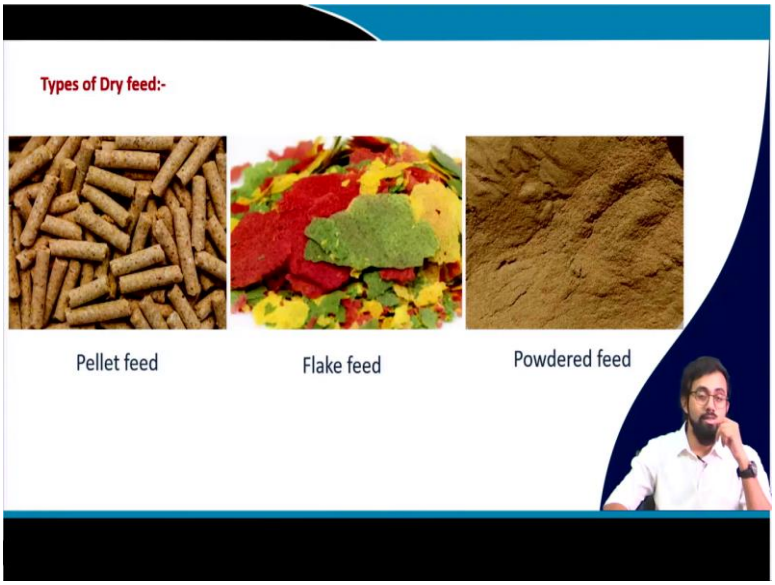
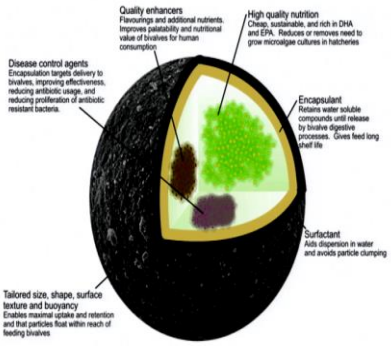


Micro–Encapsulated Feed



Source: Willer and Aldridge, 2019

Non-dry feeds - are divided into two major categories –**Wet and moist.**

Wet feeds are those which are made entirely or almost entirely from high moisture ingredients, such as 'trash' fish, waste slaughterhouse products, undried forage, etc.

- Moisture contents of about **45-70%**

Moist feeds are made from mixtures of Wet, or moist and dry raw materials, or from dry ingredients to which moisture has been added

- Usually moist feeds range from 18-45% moisture.
- There is no really clear division between 'moist' and 'wet' feeds.

The third class of products -flaked feed -is designed for aquarium fish, fish fry, and early post-larval shrimp

Steps in feed formulation

1. Gathering comprehensive knowledge and information regarding the ingredients in terms of their availability in the market, chemical composition along with their consistency, and seasonality

   ➢This will directly help to determine the cost of the ingredient and in turn the price of the feed.

   ➢Mathematical formulae are applied to calculate the amounts of each ingredient needed to be incorporated in the compounded feed mixture.

   ➢Mathematical formulae used for aquafeed formulation are:

   ✓Classical Pearson Square or Box Method

   ✓Complex Linear Programming

See this is called the pellet feed, how it looks like this pellet feeds and also in general most of the pellet feeds it can be dry, it can be sunken, it can be sinking or something or it can be a floating one. Flake feeds are there depending upon the size and then target reared species; the feed can look like a crumble feed or the powdered feed as well.

There are another very advantageous like advanced stage of feed that is being supplied nowadays at least for maximum utilization of the feed actually is the micro encapsulated feed. We use calcium alginate and all these things different linked proteins and all as a covering agent or as a final layer, so this final layer and what it this encapsulates and it how it helps actually because of this encapsulates and all because of this outer layer which is quite rigid and because of that the feed does not go waste for long period of time, first of all.

Second it can be well utilizable by the; it is actually also biodegradable I mean like not biodegradable, they can easily consume it it is not harmful that is also made up of this as I told you calcium alginates and all this linked protein that we normally use for this upper layer coating. So that is also consumable like that can also be consumed by the aquatic species or the reared aquatics species.

Plus the good thing about these things I told you like the maximum utilization of the feed is possible so that is why this micro encapsulated feeds are becoming very famous and now it has been already used all over the world majorly. Another good thing is it is not easily water soluble other feeds are when it in touch with the water after a certain moment of time it exfoliated.

And because of that it is dissolve in the water there is a chance of it there is some turbulence and but in case of micro encapsulated feed it will not dissolve in water for long very long period of time, even like it is really long period of time so the fish will get enough time to capture it and consume it for their consumption purpose. Non-dry feed it can be of wet or moist, wet one where it is like entirely moisture in nature like the trash fish, waste slaughterhouse products, undried forage, etc.

So it has a moisture content of around 45 to 70 percent, whereas the moist feed it is in between wet and dry raw material, so it is like 18 to 45 percent of the moisture content, so then we call it moist feed. It is clearly a division between the moist and the wet you can easily understand.

Another third class of products is available that is called we call flake products; it is actually designed for aquarium fish, fish fry and very early post larval shrimps and all. So what are the steps that normally we follow when we go for the feed formulation, normally gathering a comprehensive knowledge and information regarding the ingredients in terms of their availability in the market?

Chemical composition along with their consistency and seasonability is important when we discuss about the feed that we are supplying to our reared species. This can directly help to determine the cost of ingredients and in turn the price of the feed, so suppose you need huge amount of protein for rearing certain amount of species of specific type of vitamins but you know that you cannot just go 100 percent because if you go a certain particular limit it will cost you a lot.

So you have to optimize the expectation from your rearing species, their feed requirement and you have to optimize the cost that it incurs. So optimization of this cost and feed nutrient requirement is what we do in a feed formulation process by using different ingredients of different nutrient demand.

There are mathematical formulae which are applied to calculate the amount of each ingredients needed to be incorporated to be compounded feed mixture and this mathematical formula used in general the major mathematical formula that we use in aquafeed formulations are classical pearson square or box method, there is another method we use complex linear programming.

I will discuss in this lecture material how classical pearson square or box method is used and in the next lecture I will be discussing about the complex linear programming methods and how this complex linear programming is used for calculating the feed formulation or the aquafeed formulation.

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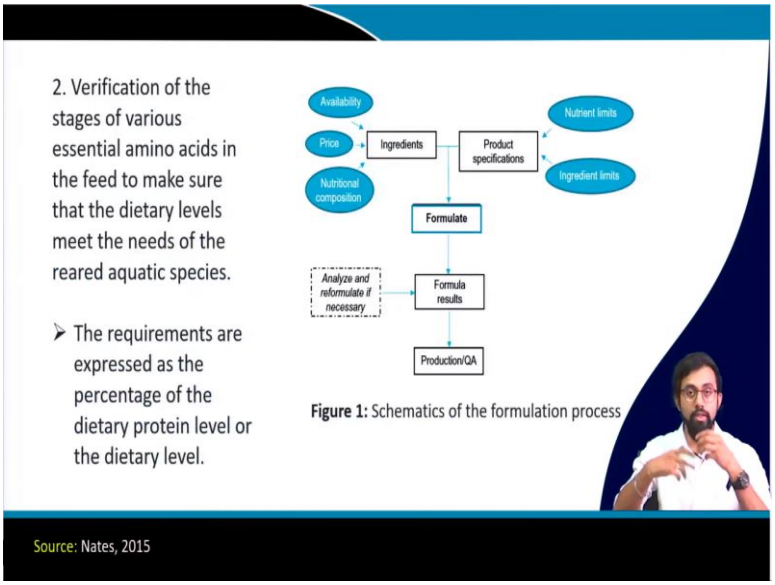

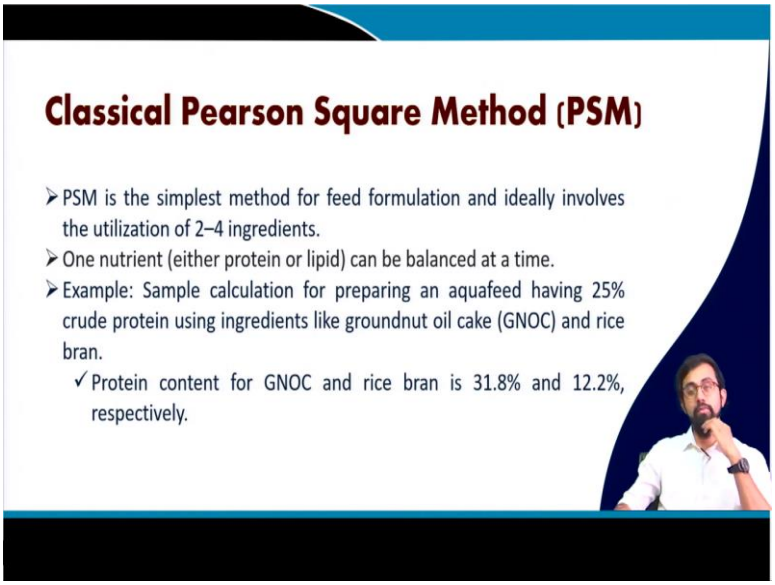

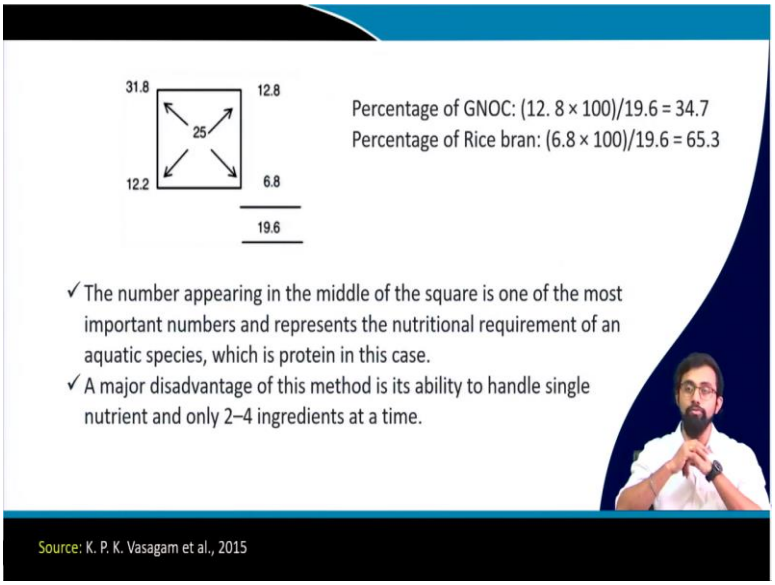

In case of the other notable things in feed formulation is like verification of the stages of various essential amino acids, so make sure that each stages of your aquatic species each stages of development of aquatic species it is supplied with the proper amount of dietary supplementation and it contains the essential amino acids.

So this essential amino acid is very minor this calculation is very sensitive because it varies raw material to raw material and what type of raw material that you will be supplying so that in what a percentage and how much dilution that you need, how much addition what is the other chemicals that you need to add to extract that amount of amino acid.

So all these things required and constituents a very huge data loading and that data if you properly analyze you need to have a proper idea about the different programming methods, how you can formulate this proper exact feed formulation process. Earlier it used to do like randomly in a broadcasting method and randomly they calculated, but now things are changing, systems are improving and people are using.

All the agriculturalists and the aquaculturists and also right now they are started making themselves well versed with all the advanced technology and there are different people from different sector actually coming together to help blooming the aquaculture sector, agriculture sector and they are working on optimization of feed formulation by using the linear programming or all these advanced technologies. So that the final feed that you will be preparing is ample enough and perfect for your target aquatic species.

In case of classical pearson square method I will discuss about it like how it looks like, how to do the calculation and all, in short we call it PSM. So is the simplest method for feed formulation, ideally involves two to four ingredients. The moment it increases the four ingredients you cannot solve using this PSM method. PSM method is only possible up to four ingredients; I will show you a very easy example how to calculate it if you want to know much more because it contains like some mathematical application and all so I will not go in details but very basic discussion, how the calculation is taking place.

So suppose I am giving one example where you have to prepare an aqua feed with 25 percent crude protein, how much percentage of crude protein you need; 25 percent in your final aqua feed. You have two sources I mean two ingredients of this crude protein, first groundnut oil cake GNOC and second is rice bran. GNOC and rice bran are the ingredients which has the source of which is actually utilized for the source of crude protein.

Now the additional information what we know? We know that in case of in case of groundnut oil cake it has a protein content of 31.8 percentages and in case of rice bran it has a protein content of 12.2 percentages. Now what are the information that we have we need final product 25 percent crude protein, raw materials we know two raw materials are provided with GNOC and rice brand 31.8 and 12.2 percentage of crude protein.

How we use this information to formulate and how we calculate what is the exact percentage of crude protein or exact percentage of GNOC or exact percentage of rice bran is actually required for our final product, final aqua feed with 25 percent crude protein. It is a very easy method like there are thousands of ways you can do that, you know it is a very basic class 9, 10 level mathematics even before that, so here is with the calculation with this box method it becomes much easier.

Suppose in the box initial crude protein concentration of GNOC is 31.8 and it is in the top left bottom top left side, in the top right you see 12.8 which is the concentration of the crude protein in the rice bran and what is the final target crude protein 25 percent you put it in the middle. Now diagonally opposite way you just simply do the calculation of subtraction how you are doing is 25 minus 12.8, how much 12.2 you put it in the just diagonally opposite side you write it in 12.2.

Same way 31.8 minus 25 is how much 6.8, you always do the mod value what value of this subtraction means only the positive values are are considered 12.2 in the bottom how it comes you understand, 25 minus 12.8, 12.2; 31.8 minus 25, 6.8.

So now you add those two these differences 12.8 plus 6.8 how much 19.6; so we need this value so percentage of GNOC will be 12.8 divided by 19.6 multiplied by 100, it is 34.7 percentage and what will be the percentage of rice bran 6.8 multiplied by 100 divided by 19.6 which is 65.3 percentage.

$$\text{Percentage of GNOC} = (12.8 \times 100)/19.6 = 34.7\ \%$$

$$\text{Percentage of rice bran} = (6.8 \times 100)/19.6 = 65.3\%$$

Suppose now I say for your own understanding I am giving you another kind of exercise just for your understanding suppose you have to have a feed which should have at least 40 percentage of crude protein, you need 40 percent as a crude protein in your final aqua feed and you take GNOC and rice bran only, same example I am giving, but suppose the percentage is different in case of GNOC like the initial crude protein concentration instead of 31.8, I am saying like it is a very raw one which is having a very low crude protein concentration say like around 22 percentage.

So 22 percent screw protein is available from the GNOC and suppose in case of rice bran it is like in a very fortified rice bran and all so because of that it has a very high protein concentration say like around 25 or 26 percentage; so say 26 percentage of crude protein available with rice bran and GNOC like what you say it is 15 or 16 they suppose like 15.

So what will be the final concentration of each of this brand, each of these things which is required for you to have a final crude protein 40 percentage? I want you guys to do that it is really tricky but I want to use your brain how you are going to do that, what kind of method you are going to do that and in order to do that you may have to in you may have to google a little bit about the feed formulation procedures and which will definitely help you.

So the number which appears in the middle of the square is the one is the most important number it represents the nutritional requirement of an aquatic species which is protein in this case and major disadvantages of this method is you cannot work with more than four ingredients at a time.

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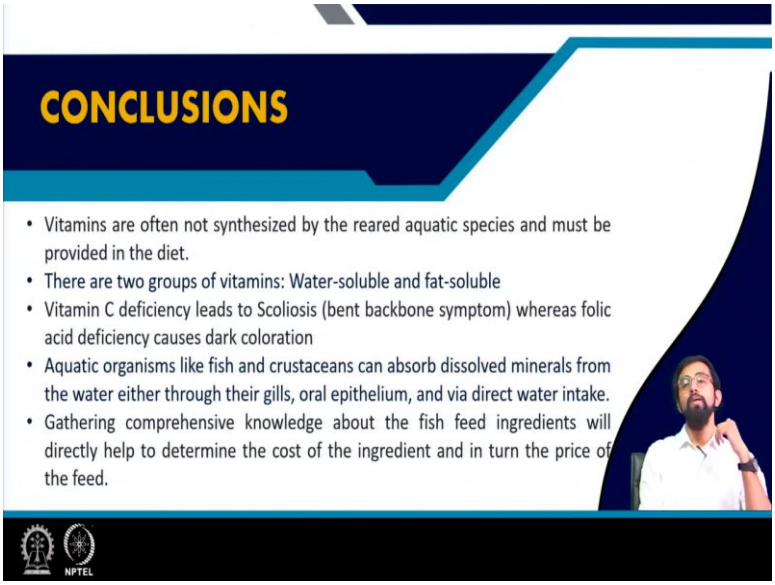

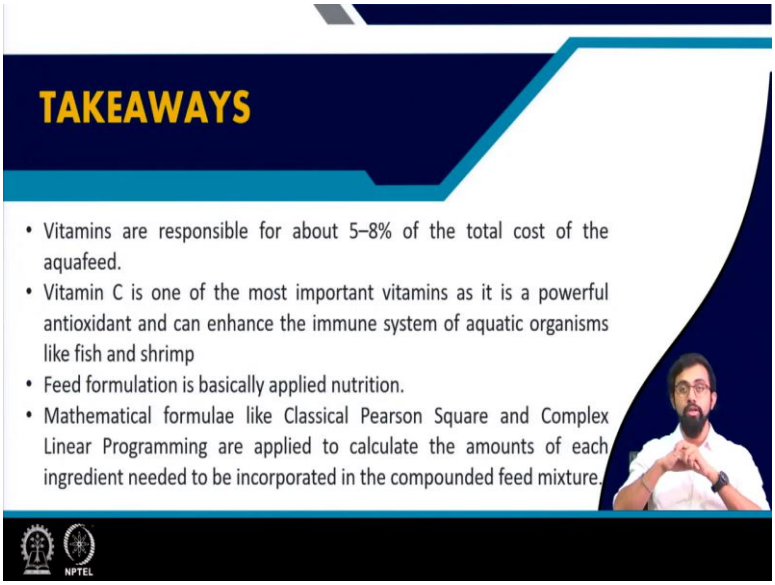

I will discuss more about this method feed formulation methods like linear programming and all in the next lecture. So in conclusion what we can see in this lecture material we discussed about the vitamins which are often not synthesized by the reared aquatic species and that is why you must need to provide it with the diet, what are the types of vitamins, water soluble and the fat soluble, different deficiency of different vitamins we discussed.

And aquatic species can absorb we discuss about the way how in general aquatic species can absorb their dissolved minerals from water either by their gills, by oral epithelium or by the direct water intake and we gathered the knowledge about the fish feed ingredients and which will help us to formulate the feed.

So what is the major takeaway from this lecture, I would say first of all vitamins are majorly it constitutes around 5 to 8 percent of the total cost of the aqua feed you have to remember this. Vitamin C is very the most important vitamin as it is a very powerful antioxidant, vitamin E is also and feed formulation is basically applied nutrition and how you do that is one of the methods we discussed classical Pearson square method and complex linear programming method we will be discussing in the coming lecture.

So these are the references that you can take a picture or you can pause the video and you can go search for it in the google, so to have a better idea about on this discussion. Thank you so much so we will discuss more about the feed formulation in the coming lecture, thank you.