Ph. D (Fish Nutrition and Feed Technology)

Course Structure – At a Glance

A	**MAJOR COURSES**			**17 Credits**
	A1	**CORE COURSES**		**9 Credits**
1	FNT 601	Bioenergetics	2+1	
2	FNT 602	Advances in Feed Technology	2+1	
3	FNT 603	Larval and Broodstock Nutrition	2+1	
	A2	**OPTIONAL COURSES**		**8 Credits**
1	FNT 604	Advances in Nutrition	2+1	
2	FNT 605	Nutrigenomics	1+1	
3	FNT 606	Nutraceuticals	1+1	
4	FNT 607	Feed Intake and Feeding Behaviour	1+2	
5	FNT 608	Nutrition and Environment	2+1	
B	**MINOR COURSES** (Courses outside major discipline / from other relevant disciplines)			**6 Credits**
C	**SUPPORTING COURSES** (Compulsory)			**5 Credits**
1	FST 601	Advanced Statistical Methods	2+1	
2	FST 602	Software for Fisheries Data Analysis and Management	0+2	
		Total Course Work Credits		**28 Credits**
D	**DOCTORAL SEMINAR**			**2 Credits**
1	FNT 691	Doctoral Seminar I	0+1	
2	FNT 692	Doctoral Seminar II	0+1	
E	**DOCTORAL RESEARCH**			**45 Credits**
	FNT 699	Doctoral Research (Semester III)	0+11	
	FNT 699	Doctoral Research (Semester IV)	0+11	
	FNT 699	Doctoral Research (Semester V)	0+11	
	FNT 699	Doctoral Research (Semester VI)	0+12	
		Total Ph. D Program Credit Hours		**75 Credits**

FNT 601	BIOENERGETICS	2+1
Objective	Energetics of biosynthesis and Bio-transformation metabolic scope	
Theory		
Unit I	Energy requirements of fish: Principles and methods; factors affecting energy requirement; energy budgeting, metabolic rate and factors affecting it.	
Unit II	Metabolic scope: herbivores, carnivores and omnivores	
Unit III	Bloodstock Energetics of feeding and digestion. Energy requirements for reproduction, Energetics of gonadal maturation and gamete production, bioenergetics of spawning, Relationship between feeding and maturation.	
Unit IV	Larval energetics: growth-mortality, metabolism and energy budget. Energy relationship between egg and hatchlings.	
Unit V	Lipid energetics: fatty acid biosynthesis and degradation. Biosynthesis of triglycerides, phospholipids, sphingolipids and cholesterol. Transport and modification of fatty acids in finfish and shellfish. Deasaturation and elongaion of n-3 and n-6 fatty acids. Role of desaturases and elongases.	
Unit VI	Carbohydrate energetics: biosynthesis and degradation, interaction of carbohydrate with lipid and protein.	
Practical	Estimation of oxygen consumption; Estimation of gross energy and digestible energy of feed; Comparison of energy requirements of carnivorous, herbivorous and omnivorous fish; Estimation of total and free cholesterol. Estimation of standard metabolic rate by Respirometer.	
Suggested Readings	1. De Silva, S. S. and Anderson, T. A. 1995. Fish Nutrition in Aquaculture, Chapman and Hall Aquaculture Series, London. 2. Evans, D. H. and Claiborne, J. B. 2006. The Physiology of Fishes. CRC Press. 3. Halver, J. E. and Hardy, R. W. 2002. Fish Nutrition. Academic Press, London. 4. Houlihan, D., Boujard, T. and Jobling, M. 2001. Food Intake in Fish. Blackwell Science Ltd., London. 5. Jobling, M. 1994. Fish Bioenergetics. Chapman and Hall, London 6. Lovell, R. T. 1998. Nutrition and Feeding of Fishes. Kluwer Academic Publishers. 7. Tyler P. and P. Calow 1985: Fish Energetics: New Perspectives. Croom Helm Ltd. Provident House, Burrell Row, Beckenham, Kent, London.	

FNT 602	ADVANCES IN FEED TECHNOLOGY	2+1
Objective	The quality of feed ingredients and their uses in feed preparation. The different types of feeds, preparation and growth evaluation.	
Theory		
Unit I	National and International scenario of aquafeed and feed ingredients availability demand and supply; international standards of feed.	
Unit II	Feed formulation: Least cost formulation, linear programming; quality of feed ingredients and their biochemical composition; protein and energy supplements; vitamins and minerals premixes.	
Unit III	Feed processing machineries; feed manufacture: processing of feed mixtures, steam pelleting, extrusion, bravo processing for non-compacting feed, stability of nutrients; factors affecting feed manufacture; effects of processing on the nutritional value of feeds; economics of feed manufacturing.	
Unit IV	Scope and exploration of new feed ingredients, associated antinutritional factors and methods of detoxification processes.	
Unit V	Storage and quality control; adventitious toxin and effect on feed safety; storage of feed and quality deterioration;	
Unit VI	Design of a feed mill unit, and record keepings.	
Practical	Analysis of anti-nutritional and toxic substances in feed ingredients and feed; formulation of diets using software. Preparation of different types of feed and their quality evaluation; Effect of feed storage on nutritional value of feed, Farm made Feed preparation.	
Suggested Readings	1. New, M. B. 1987. Feed and Feeding of Fish and Shrimp. A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture. ADCP/REP/87/26 F.A.O., Rome. 2. ADCP (Aquaculture Development and Co-ordination Programme). 1980. Fish Feed Technology, ADCP/REP/80/11.F.A.O., Rome. 3. D' Abramo, L. R., Conklin, D. E. and Akiyama. D. M. 1977. Crustacean Nutrition: Advances in Aquaculture Vol. 6. World Aquaculture Society, Baton Roughe, L. A. 4. De Silva, S. S. and Anderson, T. A. 1995. Fish Nutrition in Aquaculture. Chapman and Hall Aquaculture Series, London. 5. Guillame, J., Kaushik, S., Berqot, P. and Metallier, R. 2001. Nutrition and Feeding of Fish and Crustaceans. Springer Praxis Publishing, Chichester, U. K. 6. Halver, J. E. and Tiews, K. T. 1979. Finfish Nutrition and Fishfeed Technology Vol. I and II. Heenemann, Berlin. 7. Halver, J. E. and Hardy, R. W. 2002. Fish Nutrition. Academic Press, London.	

	8. Halver J. E. 1989. Fish Nutrition, Academic Press, San Diego, California. 9. Lovell, R. T. 1998. Nutrition and Feeding of Fishes, Kluwer Academic Publishers. 10. Muir, J. F. and Robert, D. (Eds.). 1968. Recent Advances in Aquaculture Vol.II. Blackwell Science.

FNT 603	**BROODSTOCK AND LARVAL NUTRITION**	**2+1**
Objective	Larval development and specific role of nutrients in broodstock.	
Theory		
Unit I	Larval development: Nutritional profile of egg yolk. Mechanism of egg yolk utilization. Degradation of egg yolk platelets and granules. Utilization of egg protein and amino acids lipid utilization. Influence of abiotic factors on yolk absorption.	
UNIT II	Digestive system in larvae: Ontogenesis of digestive systems, digestion and absorption of protein and lipid; mechanism of transition from endogenous to exogenous nutrition. Weaning diets and importance.	
Unit III	Nutritional status of larvae: Nutritional requirements and deficiency symptoms.	
Unit IV	Broodstock development: effect of nutrition on fecundity, fertilization, embryo development, larval quality.	
Unit V	Special broodstock diets: Special ingredients for gonadal development and ingredients affecting gonadal development. Effective feeding periods for optimum broodstock performance.	
Unit VI	Feeding methods: Manual, mechanical and automatic feeding; feeding devices and strategies, Larval feeding behaviour and feed management.	
Practical	Preparation of larval feed. Nutritional profiling of egg yolk and larvae. Nutritional analysis of live food organisms. Estimation of proteases in larvae. Estimation of gonado-somatic index and fecundity.	
Suggested Readings	1. CIFE, 1993. Training Manual on Culture of Live Food Organisms for Aqua Hatcheries. Central Institute of Fisheries Education, Versova, Mumbai. 2. De Silva, S. S. and Anderson, T. A. 1995. Fish Nutrition in Aquaculture. Chapman and Hall Aquaculture Series, London. 3. Guillame, J., Kaushik, S., Berqot, P. and Metallier, R. 2001. Nutrition and Feeding of Fish and Crustaceans. Springer Praxis Publishing, Chichester, U. K. 4. Hagiwara, A., Snell, T. W., Lubzens, E. and Tamaru, C. S. 1997. Live Food in Aquaculture. Proceedings of the Live Food and Marine Larviculture Symposium. Kluwer Academic Publishers, London. 5. Halver, J. E. and Hardy, R. W. 2002. Fish Nutrition. Academic Press, London. 6. Lovell, R. T. 1998. Nutrition and Feeding of Fishes. Kluwer Academic Publishers.	

FNT 604	ADVANCES IN NUTRITION	2+1
Objective	The mechanism of feed intake and feeding behavior and the concept of eco-friendly feed.	
Theory		
Unit I	Feeding behavior; feed intake and environment; techniques of measuring feed intake. Regulation of feed intake by neuropeptides and hormones; stimulatory peptides, inhibitory peptides; identification of gustatory feeding stimulants; Nutrient receptors and transporters hormonal control of metabolism.	
Unit II	Low cost and eco-friendly diets; optimization of carbohydrates in diets; strategies for improving protein retention; Feeding standards. Tracer techniques in fish nutrition.	
Unit III	n-3 and n-6 fatty acids, their functions and deficiencies, fatty acid oxidation and antioxidants; phospholipids.	
Unit IV	Effect of formulated diets on digestive processes in larvae and juvenile; dietary role in growth and reproduction.	
Unit V	Recent advances in feed additives, product quality.	
Unit VI	Medicated feeds, Feed and flesh quality, Carotenoids.	
Practical	Protein quality estimation (PER, NPU). Digestibility studies. Estimation of fatty acids.	
Suggested Readings	1. ADCP (Aquaculture Development and Co-ordination Programme). 1980. Fish Feed Technology. ADCP/REP/80/11.F.A.O., Rome. 2. De Silva, S. S. and Anderson, T. A. 1995. Fish Nutrition in Aquaculture. Chapman and Hall Aquaculture Series, London. 3. Guillame, J., Kaushik, S., Berqot, P. and Metallier, R. 2001. Nutrition and Feeding of Fish and Crustaceans. Springer Praxis Publishing, Chichester, U. K. 4. Halver, J. E. 1989. Fish Nutrition, Academic Press, San Diego, California. 5. Halver, J. E and Tiews, K. T. 1979. Finfish Nutrition and Fishfeed Technology Vol. I and II. Heenemann, Berlin. 6. Halver, J. E. and Hardy, R. W. 2002. Fish Nutrition. Academic Press, London. 7. Hepher, B. 1988. Nutrition of Pond Fishes. Cambridge University Press, Cambridge. 8. Lovell, R. T. 1998. Nutrition and Feeding of Fishes. Kluwer Academic Publishers.	

FNT 605	NUTRIGENOMICS	1+1
Objective	Nutritionally important gene and their interactions with nutrients. The basic study in molecular nutrition.	
Theory		
Unit I	Principles of nutrigenomics: Genomics and nutrigenomics, gene structure and regulation, nutritionally important genes, nutrient-gene interaction and expression. Methodologies in molecular nutrition.	
Unit II	Extraction of m-RNA, reverse transcription and cDNA biosynthesis, cloning techniques; genomic and differential gene expression.	
Unit III	Use of DNA probe: Blotting and hybridization, microarray; microarray nitrocellulose hybridization and labelling with P^{32} probes; quantitative real time polymerase chain reaction. (qRT PCR);	
Unit IV	Bioinformatics: Gene expression software; BLASTIN, FASTA and PHYLIP etc; relative expression software tool (REST); interpretation of microarray data; cloning technique.	
Practical	Genomic DNA, plasmid DNA and RNA extraction and isolation, m-RNA purification; cDNA synthesis by reverse transcription; Elution of PCR product for gene sequencing; Cloning, exploration of bioinformatics tools.	
Suggested Readings	1. Fingerman, M., Nagabhushanam, R. and Thompson, M. F. 1997. Recent Advances in Marine Biotechnology (vol1-3). Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi. 2. Glick, B. R. and Pasternak, J. J. 1999. Molecular Biotechnology: Principles and Applications of Recombinant DNA Technology, ASM Press, Washington, D. C. 3. Hoar, W. S. and Randal, D. J. 1969. Fish Physiology. Academy Press, New York. 4. Lehninger, A. L. 1984. Principles of Biochemistry. CBS Publishing, New Delhi. 5. Primrose, S. B. 1989. Modern Biotechnology. Blackwell Scientific, Oxford. 6. Rodney, B. 1998. Concepts in Biochemistry. Cole Publishing Company, London. 7. Kaput, J; Rodriguez, R.L 2006: Nutraceutical Genomics. Wiley Interscience, Hoboken, New Jersey.	

FNT 606	NUTRACEUTICALS	1+1
Objective	Nutraceuticals used in aquaculture and their delivery system.	
Theory		
Unit I	Definition, classification and role of different nutraceticals; mode of application; functions of acidifiers (citric acid, propionic acid, benzoic acid).	
Unit II	Exogenous enzymes (phytase, carbohydrases, proteases etc.) in feed and nutrient utilization; prebiotics and probiotics; Single cell proteins as nutraceuticals; antioxidants and their functions.	
Unit III	Chemoattractants for fish and shellfish; fish based nutraceticals and their application; Carotenoid, EPA, DHA, designer fish.	
Unit IV	Immunostimulants and their functions (nucleotide, manan oligosaccharides, beta glucan, levan, lactoferrin, sodium alginate, sulphated polysaccharides, levamisol).	
Practical	Estimation of phytase and phytate. Effect of acidifiers on pH in different parts of GI tract. Estimation of antioxidants vitamin E and vitamin C. Estimation of n-3 fatty acid.	
Suggested Readings	1. De Silva, S. S. and Anderson, T. A. 1995. Fish Nutrition in Aquaculture. Chapman and Hall Aquaculture Series, London. 2. Guillame, J., Kaushik, S., Berqot, P. and Metallier, R. 2001. Nutrition and Feeding of Fish and Crustaceans. Springer Praxis Publishing, Chichester, U. K. 3. Halver, J. E. and Hardy, R. W. 2002. Fish Nutrition. Academic Press, London. 4. Lovell, R. T. 1998. Nutrition and Feeding of Fishes. Kluwer Academic Publishers.	

FNT 607	FEED INTAKE AND FEEDING BEHAVIOUR	1+2
Objective	Understanding the mechanism of feed intake and feeding behavior.	
Theory		
Unit I	Gustation and feeding behaviour: peripheral gustation sensation, gustatory pathways in the central nervous system, taste and feeding behavior.	
Unit II	Feed intake: different techniques of feed intake: stomach content analysis, chemical markers, direct observation and video recording, demand feeder, X-radiography, Factors affecting voluntary feed intake, effect of feeding time on feed intake and growth.	
Unit III	Regulation of feed intake: Neuropeptides and hormones, Inhibitory peptides,	

	stimulator peptides, growth hormones. Identification of gustatory feeding stimulants; Nutrient receptors and transporters, hormonal control of metabolism.
Unit IV	Physiological effects of feeding: Different methods of feeding, short terms effects of a meal, tissue metabolic physiology; feeding frequencies. Physiology of starvation and feed restriction.
Practical	Measurement of feed intake by chemical marker, Feed intake measurement with respect to temperature, Experiment on feeding stimulant, Feed intake and blood glucose co-relation, Comparative intake of natural vs artificial feed. Monitoring feeding behavior of different species, Evaluation of response of fishes to feed in terms of feed detection and intake, Study of crustacean feeding behavior in different life stages, Study of digestive anatomy and morphology and their correlation with digestive physiology, Impact of feeding regimes on feed intake.
Suggested Readings	1. De Silva, S. S. and Anderson, T. A. 1995. Fish Nutrition in Aquaculture. Chapman and Hall Aquaculture Series, London. 2. Guillame, J., Kaushik, S., Berqot, P. and Metallier, R. 2001. Nutrition and Feeding of Fish and Crustaceans. Springer Praxis Publishing, Chichester, U. K. 3. Halver, J. E. 1989. Fish Nutrition. Academic Press, San Diego, California. 4. Halver, J. E. and Hardy, R. W. 2002. Fish Nutrition. Academic Press, London. 5. Hepher, B. 1988. Nutrition of Pond Fishes. Cambridge University Press, Cambridge. 6. Houlihan, D., Boujard, T. and Jobling, M. 2001. Food Intake in Fish. Blackwell Science, France. 7. Lovell, R. T. 1998. Nutrition and Feeding of Fishes. Kluwer Academic Publishers.

FNT 608	**NUTRITION AND ENVIRONMENT**	**2+1**
Objective	Understanding influence of environment on nutrient utilization	
Theory		
Unit I	Nutrient dynamics: Influence of nutrient cycles on web/chain. Influence of detrital food web on nutrient distribution. Nutrient loading through feed and fertilizer.	
Unit II	Stress and nutrition: influence of stress on feed intake, digestion and absorption. Stress indicator and nutritional strategies for mitigate stress.	
Unit III	Eco-friendly feed: Use of exogenous phytase and acidifiers, high energy diets, methods of enhancing feed digestibility, biofloc and probiotics influences.	
Unit IV	Nutritional pathology: Deficiency and imbalance diseases: essential amino acids, essential n-3 and n-6 fatty acids deficiencies. Micronutrients: fat-soluble vitamins, water-soluble vitamins; macro-elements, trace-elements and mineral toxicity.	
Unit V	Natural feed augmentation for increasing fish production, Different food chains in	

	aquatic ecosystem, Feeding behavior and feeding niche, Effect of environmental parameters on appetite of fish.
Unit VI	Impact of feed and nutrition on environment, Nutrients affecting the water quality. Nutritional strategies to reduce the nutrient flow in aquaculture system, Contribution of feed waste to organic load of aquaculture production systems. Role of additives in reducing environmental pollution.
Practical	Study of influence of thermal stress, hypoxia, salinity and pH. Stress enzyme (LDH, catalase, SOD, glutathione peroxidase), stress hormone (cortisols) and sex steroid hormone.
Suggested Readings	1. ADCP (Aquaculture Development and Co-ordination Programme). 1980. Fish Feed Technology. ADCP/REP/80/11.F.A.O., Rome. 2. De Silva, S. S. and Anderson, T. A. 1995. Fish Nutrition in Aquaculture. Chapman and Hall Aquaculture Series, London. 3. Guillame, J., Kaushik, S., Berqot, P. and Metallier, R. 2001. Nutrition and Feeding of Fish and Crustaceans. Springer Praxis Publishing, Chichester, U. K. 4. Halver, J. E. 1989. Fish Nutrition, Academic Press, San Diego, California. 5. Halver, J. E and Tiews, K. T. 1979. Finfish Nutrition and Fishfeed Technology Vol. I and II. Heenemann, Berlin. 6. Halver, J. E. and Hardy, R. W. 2002. Fish Nutrition. Academic Press, London. 7. Hepher, B. 1988. Nutrition of Pond Fishes. Cambridge University Press, Cambridge. 8. Lovell, R. T. 1998. Nutrition and Feeding of Fishes. Kluwer Academic Publishers.