FEEDS AND FEEDING STRATEGIES IN AQUACULTURE

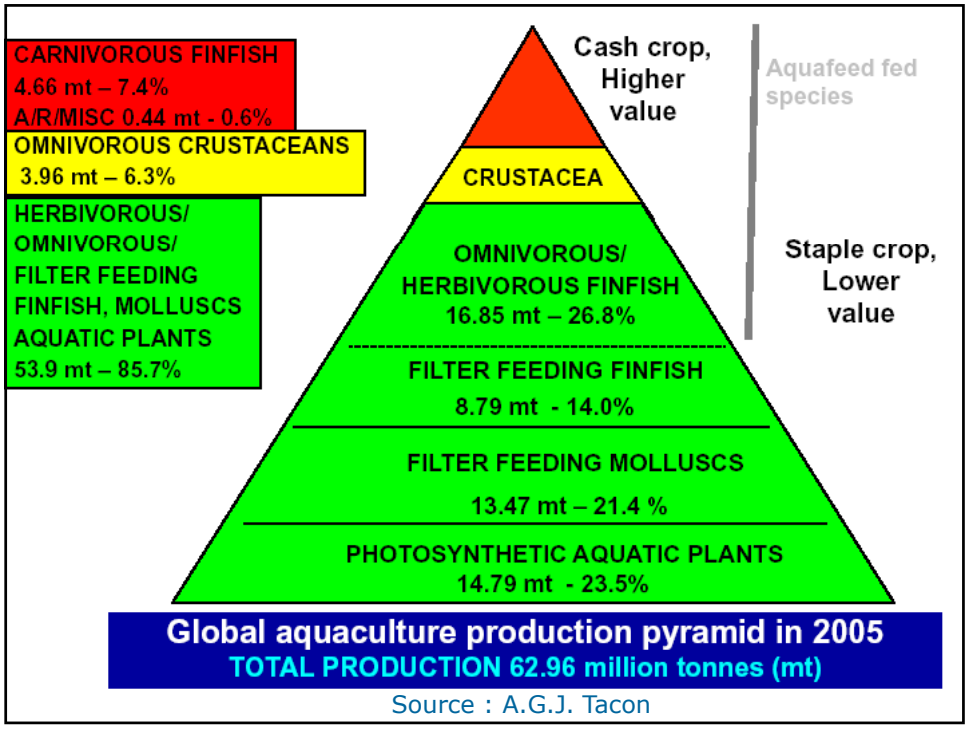
M.C. Nandeesha
Centre for Aquaculture Research
& Development.
St. Xaviers Bishramganj
Bishramganj - 799103, Tripura, India.

TOP AQUACULTURE PRODUCERS IN 2006 (FAO,2008)

Total production :66.75mmt,US$ 86.23 billion

•China (1st)	45.30 mmt (67.9%)	$ 43.66 billion (1st)
•India	3.13mmt	$ 3.43 billion
•Indonesia	2.12mmt	$ 2.58 billion
•Philippines	2.09mmt	$ 1.15 billion
•Vietnam	1.69mmt	$ 3.33 billion
•Thailand	1.38mmt	$ 2.22 billion
•Korea rep.	1.28mmt	$ 1.69 billion
•Japan	1.22mmt	$ 4.15 billion
•Bangladesh	0.89mmt	$ 1.36 billion
•Chile (10th)	0.83mmt	$ 4.48 billion(2nd)
•Spain (17th)	293,288mt	$ 361,554 million

Asia 92%, Americas 3.3% , Europe 3.2% , Africa 1.1%



Source : A.G.J. Tacon

Target commodities

- Tilapia
- Asian sea bass
- Groupers
- Snake head
- Seaweeds

Nutrition of fish and shrimp

- PROTEIN
- FAT
- CARBOHYDRATE
- VITAMINS
- MINERALS
- ENERGY

ROLE OF NATURAL FOOD IN FISH AND SHRIMP DIET

- MOTHER'S MILK
- PROTEIN -52.1%
- FAT-27.3%
- Carbohydrate -7.7%
- ENERGY-3.9 kcal/g
- SHRIMP AND FISH CAN GROW ON NATURAL FOOD FILTRATION

Proximate analysis of organisms serving as food for pond fishes (Dry matter composition)

Organism/ Group	Dry matter	Protein	Carbohydrate	Lipid	Ash	Energy (Kcal/Kg)
Bacteria						
Algae				4.7	10	5.4
Cyanophyta (blue greens)		31.3		2.2	13	46.7
Chlorophyta (green)	16.8	17.6		3.7	26.9	3773
Phaeophyta (brown algae)	14.1				32.3	3056
Bacillariophyceae (diatoms)		30.7		9.9	38.3	3654
Rhodophyta (red algae)	21.7				32.1	3170
Aquatic macro-vegetation	15.8	14.6		4.5	13.9	3906

Organism/ Group	Dry matter	Protein	Carbohydrate	Lipid	Ash	Energy (Kcal/Kg)
Hemiptera (water bugs)	26	68.8				5150
Trichoptera (caddisflies)	14.8	34.7			11.8	5019
Diptera	16	55.3			6.9	5177
Chironomids (larvae)	19.1	59	22.5	4.8	5.8	5034
Molluscs	32.2	39.5	7.5	7.8	32.9	3889
Aquatic Detritus	91.5				12.4	4791

Since the values are averages of figures collected from different sources they do not necessarily add up to 100%
Source: Modified from Helper (1988)

Organism/ Group	Dry matter	Protein	Carbohydrate	Lipid	Ash	Energy (Kcal/Kg)
Rotifers	11.2	64.3		20.3	6.2	4866
Oligochaetes	7.3	49.3		19	5.8	5569
Leeches	24	61			5.1	5432
CRUSTACEA						
Artemia	11	61.5		19.5	10.1	5835
Cladocera	9.6	56.5	28.2	19.3	7.7	4800
Copepoda	10.3	52.3	9.2	26.4	7.1	5445
Ostracoda	35	41.5				5683
Malacostraca (higher Crustacea)	24.6	49.9	18.4	20.3	19.6	5537
Insects	23.2	55.9	20.1	18.6	4.9	5075
Stone flies						4900
Mayflies	17.6	50.2			3.7	5046

Table 4: Composition of organic manures (as % by weight)

Manure	C:N Ratio	% Moisture-free basis		
ANIMAL MANURES		N	P	K
Buffalo	19	1.3	0.55	0.59
Cattle	19	1.91	0.56	1.40
Sheep	29	1.87	0.79	0.92
Goat * Sheep		1.5	0.72	1.38
Horse	24	2.33	0.83	1.31
Pig	13	2.8	1.36	1.38
Human	8	7.24	1.72	2.41
Poultry manure	9	3.77	1.89	1.76

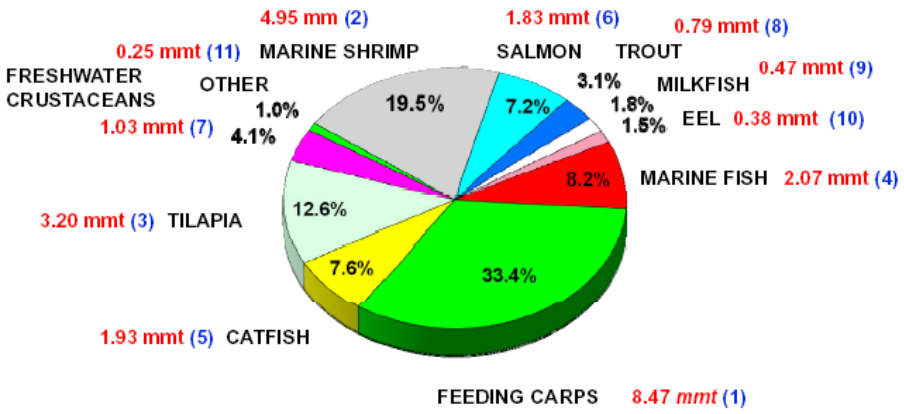
Nutrient solubility from fertilizers

Fertilizers	Nutrient solubility (%)	
	Phosphorus	Nitrogen
Superphosphate	4.6	-
Triple superphosphate	5.1	-
Monoammonium phosphate	7.1	5,1
Diammonium phosphate	16.8	11.7
Sodium nitrate	-	61.7
Ammonium sulphate		85.9
Ammonium nitrate		98.8
Calcium nitrate		98.7

Manure	C:N Ratio	% Moisture-free basis		
ANIMAL MANURES		N	P	K
Duck manure	10	2.15	1.13	1.15
Rabbit manure		1.72	1.30	1.08
URINE				
Buffalo		2.05	0.01	3.78
Cattle		9.74	0.05	7.78
Sheep		9.90	0.10	12.31
Goat + Sheep		9.64	0.14	
Pig		10.88	1.25	17.86
Human	0.8	17.14	1.57	4.86

Estimated global compound aquafeed production in 2006 for major farmed species

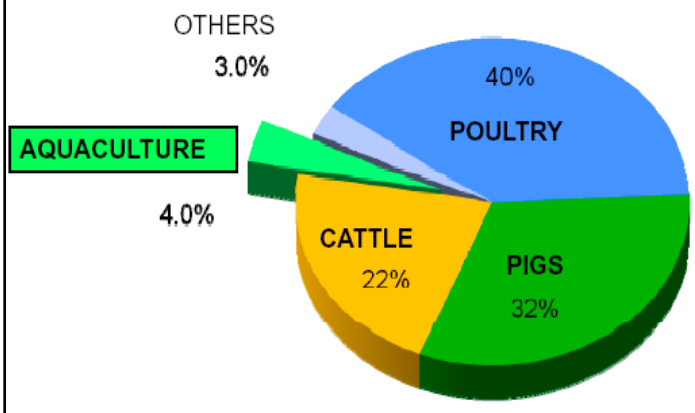
(expressed as % total aquafeed production, dry as-fed basis in million tonnes: Tacon & Metain, 2008)



Total estimated compound aquafeed production 25.36 million tonnes

Estimated global industrial feed production in 2006 for major farmed animal species

(values expressed as % dry as-fed basis)



USA	151.7 mmt
EU-25	140.4 mmt
China*	77.5 mmt
Brazil	48.4 mmt
Mexico	25.0 mmt
Japan	23.4 mmt
Canada	22.9 mmt
Russia	18.1 mmt
Korea	14.6 mmt
India	10.3 mmt

* 111 mmt (total)

Total estimated global industrial feed output in 2006 – 635 mmt

(Source: World Feed Panorama: Gill, 2007)

Contents lists available at ScienceDirect

Aquaculture

journal homepage: www.elsevier.com/locate/aqua-online

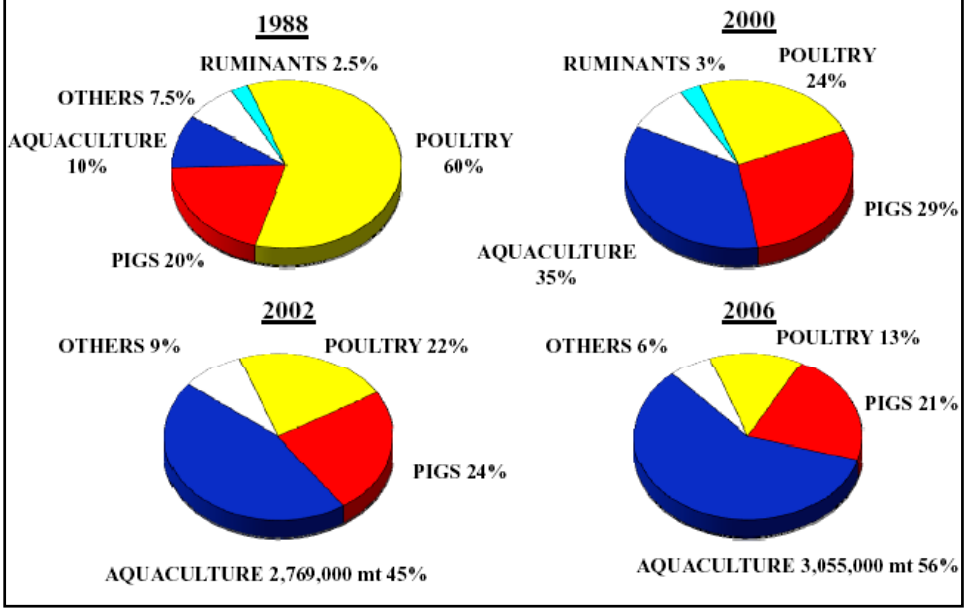
Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects

Albert G.J. Tacon [a,*], Marc Metian [b]

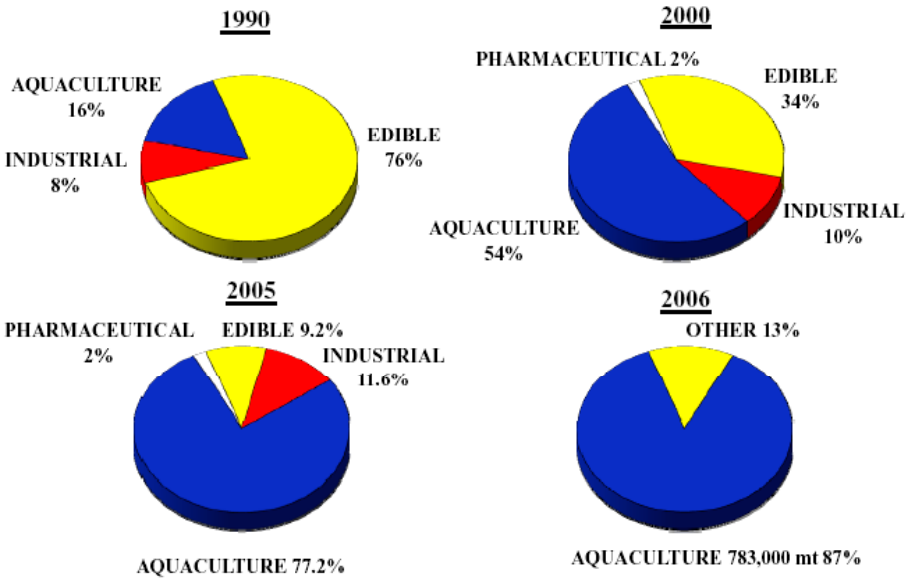
[a] Aquatic Farms Ltd, 49-139 Kamehameha Hwy, Kaneohe, HI 96744, USA
[b] Hawaii Institute of Marine Biology, University of Hawaii, Kaneohe, P.O. Box 1346, Kaneohe, HI 96744, USA

Article history:
Received 17 June 2008
Received in revised form 9 August 2008
Accepted 11 August 2008
Available online xxxx

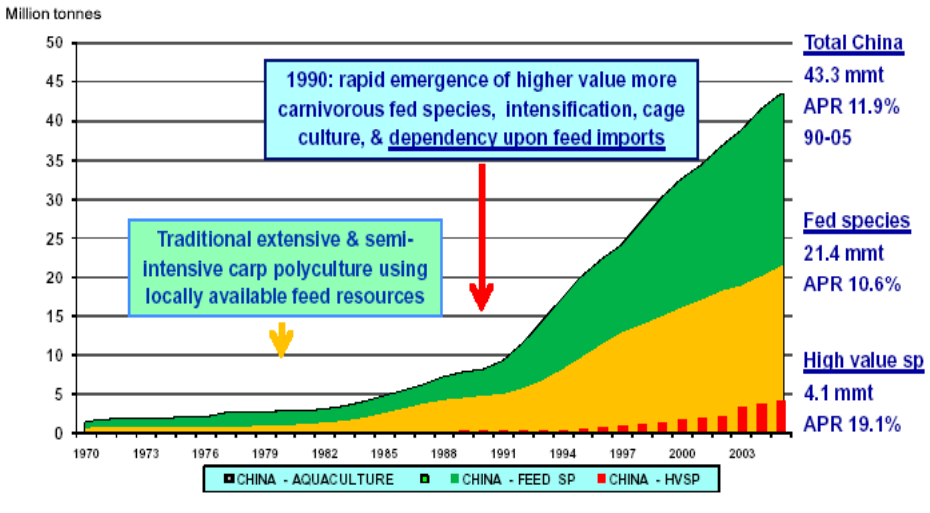
GLOBAL EVOLUTION OF FISH MEAL USE IN COMPOUND AQUAFEEDS (Source: Barlow & Pike, 2001; Jackson, 2007)



EVOLUTION OF FISH OIL USE IN COMPOUND AQUAFEEDS
(Source: Barlow & Pike, 2001; Jackson, 2007)



21.4 mmt or 49.5% total Chinese aquaculture production in 2005 is dependent upon the external provision & supply of feed inputs (66.9% rest of world), including industrially compounded aquafeeds, farm-made aquafeeds, and forage/trash fish/invertebrates



Feed presentation

- **How to present the feed**
  –wet /dry/semi moist
- **How to apply the feed**
  Tray /Spray /Automatic feeder/
- **How often to feed**
  2 times/4 times /6 times /8 times
- **When to feed**
  Day time / night time

FEED CONVERSION RATIO

- Age
- Environment
- Quality of feed ingredients
- Processing method adopted
- Feeding frequency
- Feed presentation time
- Feed presentation method ...

Reported nutrient loss from a pelleted diet after one hour immersion period

Nutrient	Level at start	Level after one hour	Percent loss
Dry matter (%)	100	81	19
Crude protein (%)	52	41	21
Carbohydrate (%)	16	8	50
Vitamin C(mg/kg)	3089	332	89
Thiamine (mg/kg)	29.5	0.7	98
Riboflavin (mg/ kg)	55	7.5	86
Pyridoxine(mg/kg)	14	1	93
Niacin (mg/kg)	120	17	86
Inositol (mg/kg)	4000	1928	52
Choline (mg/kg)	3368	1835	45
Pantothenate (mg/kg)	100	5.9	94

Nutrient requirements for fish and Prawn as percentages of diet,mg/kg, diet, or International Units (IU) per kilogram of diet (as-fed basis)

Nutrients	Asian Sea bass	Shrimp (*P.monodon*)	Groupers	Tilapia	Snake head (C. Striata)
Energy Base (kcal DE/kg diet)	3000	3400	3700	3000	3100
Protein, crude(digestible), (%)	42-45	25-45	40-50	32 (28)	43
Fat (%)	12	6	4-9	5.5	6
Fibre (%)	7	3		6	
Calcium (%)	0.6	2	NT	R	
Chlorine (%)	N/a	N/a	NT	NT	
Magnesium (%)	N/a	0.3	0.05	0.06	
Phosphorous (%)	0.4	1	0.6	0.5	
Potassium (%)	N/a	1	NT	NT	
Sodium (%)	R	N/a	NT	NT	
Copper (mg/kg)	N/a	N/a	3	R	
Iodine (mg/kg)	N/a	N/a	NT	NT	
Iron (mg/kg)	N/a	0.02	150	NT	

Nutrients	Asian Seabass	Shrimp (*P.monodon*)	Common carp	Tilapia	Snake head (C.striata)
Zinc (mg.kg)	N/a	80	30	20	
Selenium (mg/kg)	R	0.17	NT	NT	
A (IU/kg)	N/a	10000	4000	NT	
D (IU/kg)	N/a	2000	NT	NT	
E (IU/kg)	R	200	100	50	
K (IU/kg)	N/a	10	NT	NT	
Water-soluble vitamins					
Riboflavin (mg/kg)	R	R	7	6	
Pantothenic acid (mg/kg)	15-90	100	30	10	
Niacin (mg/kg)	R	140	28	NT	
Vitamin B_{12} (mg/kg)	R	0.05	NR	NR	
Choline (mg/kg)	R	R	500	NT	
Biotin (mg/kg)	R	1	1	NT	
Folate (mg/kg)	R	R	NR	NT	
Thiamin (mg/kg)	R	30	0.5	NT	
Vitamin B... (mg/kg)	10 May	R	6	NT	

Nutrients	Asian Sea bass	Shrimp (*P.monodon*)	Common carp	Tilapia	Snake head (C.striata)
Myoinsitol (mg/kg)	R	600	440	NT	
Vitamin C (mg/kg)	25-30	R	R	R	
Arginine (%)	3.8	1.63	1.31	1.18	
Histidine (%)	R	0.46	0.64	0.48	
Isoleucine (%)	R	0.71	0.76	0.87	
Leucine (%)	R	1.47	1	0.95	
Lysine (%)	4.9	1.54	1.74	1.43	
Methionine + Cystine (%)	2.2	0.85	0.94	0.9	
Phenylalanine + Tyrosine (%)	R	1.63	1.98	1.55	
Threonine (%)	R	1.01	1.19	1.05	
Tryptophan (%)	R	0.28	0.24	0.28	
Valine (%)	R	0.89	1.1	0.78	
N-3 fatty acids (%)	R	R	1		
N-6 fatty acids (%)	R	R	1	0.5-1	

Note: These requirements have been determined with higher purified ingredients in which the nutrients are highly digestible, therefore the values presented represent near 100% bioavailability. R, required in diet but quantity not determined: NR, no dietary requirement demonstrated under experimental conditions: NT, not tested, n/a, not available and E, estimated. Data from various published sources.

Strategies

ALTERNATE FEED SOURCES

- Conventional aquatic animal protein meals:- fish meals, fish oil , squid meals, crustacean meals, krill meals.
- Terrestrial vertebrate animal by–product meals:- meat meal , meat & bone meal, feather meal , poultry by-product meal , hatchery and chicken egg meals, blood meal & products....
- Terrestrials and aquatic invertebrate animal protein meals:- marine polychaetes , terrestrial worms, insect pupae/larvae, krill, copepods...
- Plant oilseed & pulse meals:- Whole or extracted oil seed meals , concentrates & isolates – Soya , rapeseed, sunflower , mustard, omega-3 fortified...

Contd.....

- Brewing/fermentation meals:- SCP-yeast , algae, bacterial biomass, brewers & distillers grains & solubles....
- Cereals and flour/milling products:- middlings, mill run , bran, gluten –rice , wheat , maize , sorghum...
- Agriculture waste/ products:- fruit wastes, pulp, cannery , leaves , tubers , roots , kitchen scraps...
- Biofuel /biodiesel byproduct :- yeasts, DDGS

Terrestrial livestock proteins and Fats.

- Terrestrial animal by- product meals represent the largest source of animal protein and lipid available to the aqua feed industry.
- For example in 2006 the U.S. alone slaughtered :-
  33.8 million cattle (50% not used for human food) ,
  104.8 million hogs (50% not used for human food),
  9.0 billion chicken (37% not used for human food),
  255 million turkeys (36% not used for human food)
- U.S. generated :-9.6 million tonnes of rendered products in 2006 (4.3F/5.3M)
- Globally :- 15-30 mmt of rendered products : APR 2.8% / year

Plant protein meals....

Aquaculture Research, 2007, 38, 551–579 doi: 10.1111/j.1365-2109.2007.01704.x

Expanding the utilization of sustainable plant products in aquafeeds: a review

Delbert M Gatlin III[1], Frederic T Barrows[2], Paul Brown[3], Konrad Dabrowski[4], T Gibson Gaylord[1], Ronald W Hardy[5], Eliot Herman[6], Gongshe Hu[7], Åshild Krogdahl[8], Richard Nelson[9], Kenneth Overturf[1], Michael Rust[10], Wendy Sealey[5], Denise Skonberg[11], Edward J Souza[7], David Stone[5], Rich Wilson[9] & Eve Wurtele[12]

PLANT PROTEIN CONCENTARATES

- Canola & Rapeseed Protein Concentrate
- Corn/Maize Gluten Meal
- Cowpea Protein Concentrate
- Leaf Protein Concentrate
- Lupin Protein Concentrate
- Pea Protein Concentrate
- Potato Protein Concentrate
- Rice Protein Concentrate
- Soybean Protein Concentrate
- Wheat Gluten Meal
- General & Anti-Nutritional Factors

Endogenous anti-nutritional factors reportedly present within plant oilseeds and pulses commonly used within aquafeeds for farmed fish and shrimp (adapted from Liener, 1980 and Tacon, 1992)

	ANTI-NUTRITIONAL FACTOR[1/]
OILSEEDS	
Groundnut *Arachis hypogaea*	1 (T,C,Pl),2,5,6,8
Rapeseed *Brassica campestris napus*	1 (T),3,5,7
Indian mustard *Brassica juncea*	1 (T),3,13
Sunflower *Helianthus annuus*	1 (T),6,7,20
Cottonseed *Gossypium* spp.	5,8,10,12,24
Linseed *Linum usitatissimum*	4,5,8,13,15
Sesame *Sesamum indicum*	5
Crambe *Crambe abyssinica*	3
Soybean *Glycine max*	1 (T,E,C,Pa,In),2,3,5,6,8,11,12, 14,16,17,27

1/1-Protease inhibitors (T-trypsin, C-chymotrypsin, Pl-plasmin, Pr-pronase, Th-thrombin, S-subtilisin, En-endopeptidase, In-insect proteases, Pa-papain, E-elastin, Mc-microbial proteases), 2-Phytohaemagglutinins, 3-Glucosinolates, 4-Cyanogens, 5-Phytic acid, 6-Saponins, 7-Tannins, 8-Estrogenic factors, 9-Lathyrogens, 10-Gossypol, 11-Flatulence factor, 12-Anti-vitamin E factor, 13-Anti-thiamine factor, 14-Anti-vitamin A factor, 15-Anti-pyridoxine factor, 16-Anti-vitamin D factor, 17-Anti-vitamin B12 factor, 18-Amylase inhibitor, 19-Invertase inhibitor, 20-Arginase inhibitor, 21-Cholinesterase inhibitor, 22-Dihydroxyphenylalanine, 23-Mimosine, 24-Cyclopropenoic acid, 25-quinolizadine alkaloids, 26-canavanine, 27-allergens

Mixed Feeding schedules

Table 1: Summary results of previous studies on mixed feeding schedules in fish. LP-low protein diet; HP- High protein diet; the numbers in front of LP and HP indicate the number of days each of these diets were fed

Species	Rearing conditions	Feeding habits	Initial Wt (g)	Feed used (% Protein content)	Best schedule
Catla catla	Outdoor cement tanks	Omnivore	0.5	15.9 (LP), 31.8 (HP)	1LP/3HP
C. catla	Earthen ponds	Omnivore	2.2	9.5 (LP), 42.6 (HP)	1HP/1LP
Channa striata	Indoor fibreglass tanks	Carnivore	0.6-1.0	33.5 (A), 35.1 (B), 46.7 (C)	1A/2C
Cyprinus carpio	Outdoor cement tank	Omnivore	1.9	16.4 (LP), 31.0 (HP)	1LP/3HP
C. carpio	Earthen ponds	Omnivore	1.1-5.1	9.5 (LP), 42.6 (HP)	1HP/1LP
C. carpio	Outdoor cement tank	Omnivore	0.53	16.0 (A), 26.2 (B), 31.7 (C)	2A/2C
C. carpio	Outdoor cement tanks	Omnivore	0.3	16.7 (A), 19.7 (B),	25.6 (C), 30.9 (D)
Labeo rohita	Outdoor cement tank	Omnivore	0.8	15.9 (LP), 31.8 (HP)	1HP/1LP
L. rohita	Indoor plastic tanks	Omnivore	3.1-4.1	18.4 (LP), 38.9 (HP)	2LP/3HP
L. rohita	Earthen ponds	Omnivore	2.7-20.6	9.5 (LP), 42.6 (HP)	1HP/1LP
M. peelii peelii	Indoor glassfibre tanks	Carnivore	22.8	40.6 (LP), 50.0 (HP)	1HP/1LP
O. niloticus	Indoor glassfibre tanks	Omnivore	0.2-1.1	18.2 (LP), 30.4 (HP)	2LP/3HP
O. niloticus	Indoor glassfibre tank	Omnivore	1.9	18.0 (LP), 25.0 (HP	1LP/2HP& 1LP/3HP
O. niloticus	Outdoor ponds	Omnivore	33 to 37	33 (HP), 22 (LP)	2HP/3LP

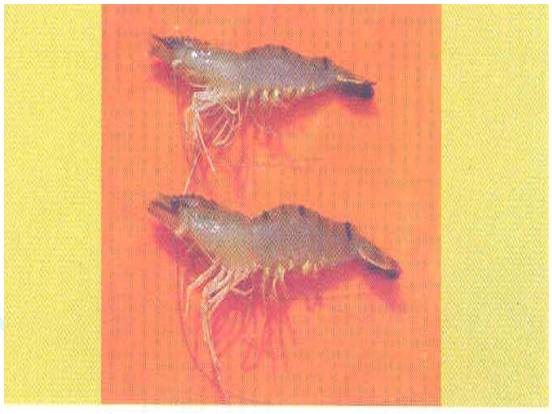
Biofloc technology

Periphyton production

Fermentation technology

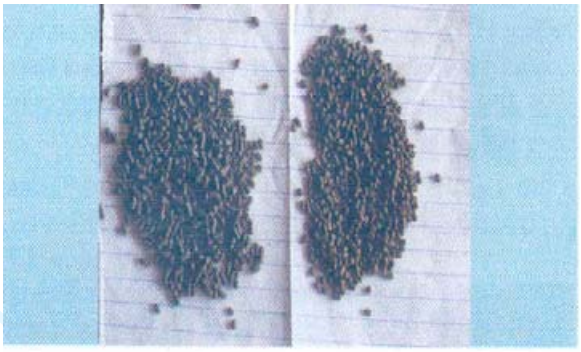
- In case of soybean products fermentation has been known to influence the growth of fish
- Rice bran single biggest commodity used in aquaculture
- Nutrients availability can be improved by fermentation process

MALE AND FEMALE GROWTH



Females eat less , grow faster ; even size is same – females ate less than males – Moss and Moss (2006)

Pellet size – Does it matter ?



Length of pellet and diameter had no effect on growth (Mishra , 2006)

CONCLUSION

- As in human, recognition that farmed aquatic animal do not have a specific dietary requirement for a particular ingredients or food source (such as fish meal or fish oil), but rather have a specific dietary requirement 40 or so essential nutrients (whether they be contained within fish , a plant or animal or blood meal is irrelevant);
- Global recognition that terrestrial animal by-product meal, including non- ruminant blood meal and blood products , represent the largest and largely untapped source of animal protein and lipid available within the international market place for the aqua feed industry;
- We will need All the ingredients we can get : both plant and animal , provided they can be sustainably produced , are cost-effective , & nutritionally & environmentally sound for the target species in question.

Fish Feed Meal Operation

Women's are doing grinding of MOC

Mixing of the Feed Ingredient

Pelleting of the Feed

Drying of the Feeds by Mechanical dryer

Sun drying of the feed before marketing