Aquafeeds and Nutrition

ROLE OF FEEDS IN PROFITABLE AND SUSTAINABLE SHRIMP FARMING

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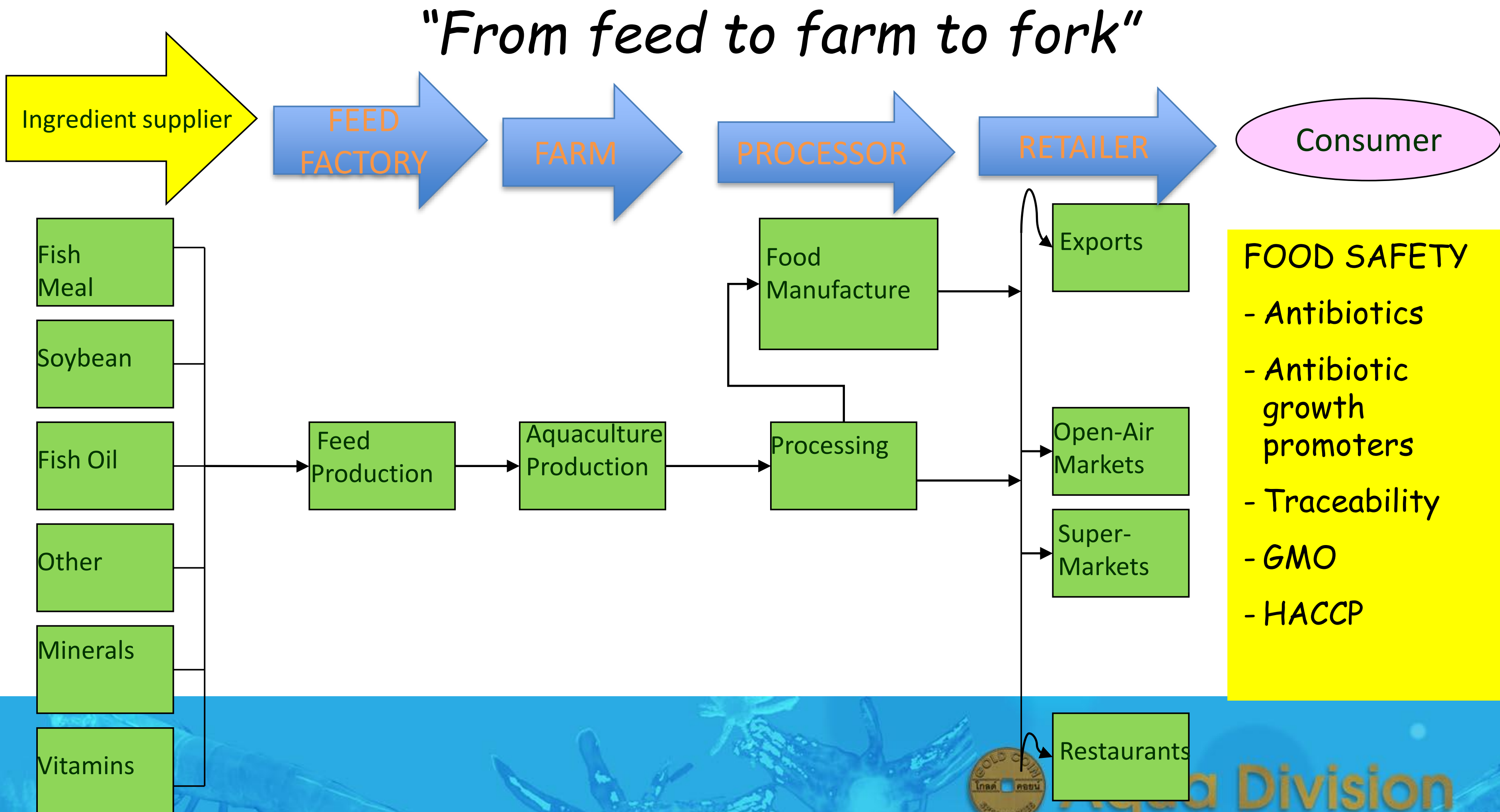
1. **Nutrition and feed manufacture**

2. **Role of feeds in growth and combating disease**

Feed: the first link in the food supply chain



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What goes into fish and shrimp feeds?

- **The feed must meet the nutrient requirements.**
  - **Ingredients selected must supply the types and amounts of nutrients required**
- **The feed must**
  - **Possess the correct physical properties**
  - **Be Environmentally sound**
  - **Lends itself to processability**
  - **Be Economically viable**

What goes into fish and shrimp feeds?

The feed must meet the nutrient requirements.

- Data from published literature, NRC, AAFFD, self generated data, shared data

Nutrient requirements – Penaeus monodon

Energy | Protein | Water – H_2O

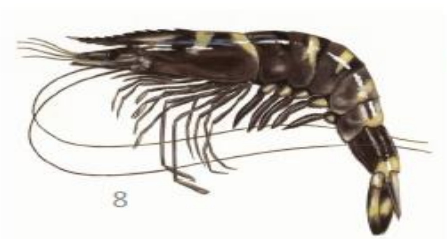
Arg | His | Iso | Leu | Lys | Met | Phe | Thr | Try | Val

18:2n-6 | 18:3n-3 | 20:4n-6 | 20:5n-3 | 22:6n-3 | Sterols | Phospholipids

Ca | Mg | P | K | Na | Cu | I | Fe | Mn | Se | Zn

A | D | E | K | B_1 | B_2 | B_6 | Pa | Ni | Bio

B_{12} | Fo | Ch | In | C



Score = 38/45 (unchanged from 2014)

Glencross 2015 TARS

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Stress and energy requirement

Table8 a. Recommended nutrient levels in commercial shrimp feeds.

Shrimp size (g)	Protein (%)	Lipid (%)	Cholesterol (%)
0.0-0.5	45%	7.5%	0.40%
0.5-3.0	40%	6.7%	0.35%
3.0-15	38%	6.3%	0.30%
15-40	36%	6.0%	0.25%

Tacon, 2002

Product Specification

Feed Code	NUTRITION COMPOSITION OF FEED					
	Feed (Type)	Protein (Min.%)	Fat (Min.%)	Fiber (Max.%)	Ash (Max.%)	Moisture (Max.%)
KJV 1	Crumble	37	5	2	13	11
KJV 2A	Crumble	37	5	2	13	11
KJV 2B	Crumble	37	5	2	13	11
KJV 3S	Pellet	33	5	2	13	11
KJV 3M	Pellet	33	5	2	13	11
KJV 3L	Pellet	33	5	2	13	11
KJV 4	Pellet	33	5	2	13	11

Item / Feed No.	PL-1	PL-2	PL-3	STARTER	GROWER	FINISHER
Feed Form	Crumble	Crumble	Crumble	Pellet	Pellet	Pellet
Feed size (mm)	0.5 ~ 1.2	1.2 ~ 2.2	1.6, L2~3	1.8, L2~4	2.0, L3-5	2.2, L4-6
Shrimp size (g)	PL 15 ~ 35	PL 35 ~ 5 g	PL 35 ~ 5 g	5 ~ 8 g	15 ~ 25 g	25 g up
Crude Protein (no less than)	40%	40%	40 %	38%	38%	37%
Crude Fat (no less than)	5%	5%	5%	5%	5%	5%
Fiber (not more than)	5%	5%	5%	5%	5%	5%
Moisture (not more than)	10%	10%	10%	10%	10%	10%
Ash (not more than)	15%	15%	15%	15%	15%	15%
Hydrochloride Insoluble (not more than)	2%	2%	2%	2%	2%	2%

Code	Packaging (kg)	Type	Protein (min. %)	Fat (min. %)	Fiber (max. %)	Ash (max. %)	Moisture (max. %)
NT3S	10	Pellet	30	5	4	11	11
NT3M	25	Pellet	30	5	4	11	11
NT3L	25	Pellet	30	5	4	11	11
NT4	25	Pellet	28	5	4	11	11

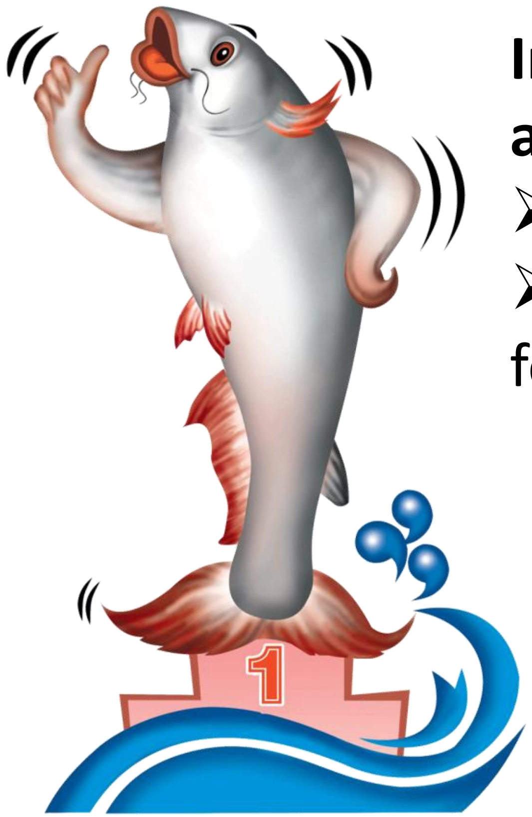
NUTRITIONS	PRODUCT CODE					
	VANA 1	VANA 2	VANA 3	VANA 3P	VANA 4	VANA 5
Crude Protein (%) min	40	40	40	40	38	38
Crude fat (%)	5 - 7	5 - 7	5 - 7	5 - 7	5 - 7	5 - 7
Crude fiber (%) max	4	4	4	4	4	4
Crude Ash (%) max	14	14	14	14	14	14
Moisture (%) max	11	11	11	11	11	11
Feed type	crumble	crumble	crumble	pellet	pellet	pellet
Packing (kg)	10	10	10	20	20	20
Diameter (mm)	0.1 - 0.2	0.2 - 0.6	0.6 - 1.5	1.4	1.6	1.8

Results from Internet search

Nutritional value of aquafeed

Nutrient	903SK0615A Classic Jun 15 Analysis	903SK0615S Classic Jun-15 (A) Analysis
DM	89.681987	89.621945
CP	39.201829	38.996968
EE	8.048015	7.739536
CF	1.520714	1.176603
ASH	12.464193	11.925501
MOI	10.091832	10.146957
CA	1.645472	1.533976
P	1.393126	1.379654
CA:P	1.181136	1.111856
NA	0.092433	0.092553
K	0.23175	0.23203
GE	4099.012306	4083.370658
LYS	2.246639	2.238479
MET	0.899979	0.900121
M+C	1.177986	1.155767
CYS	0.470787	0.462287
THR	1.402376	1.386071
TRY	0.380617	0.377878
ARG	2.263585	2.212779
VAL	1.794403	1.7866
LEU	2.77959	2.777375
ISOL	1.369146	1.337135
HIS	0.953399	0.960769
PHE	1.653429	1.645469
STARCH	17.449887	17.724546
CHOLINE	13.11766	13.128488

What goes into fish and shrimp feeds?



Ingredients selected must supply the types and amounts of nutrients required

- ➢ Nutrient composition of ingredients
- ➢ Bio-available nutrient contributions of feed ingredients – i.e High Digestibility

Raw materials: role in feed quality

ROLE OF INGREDIENTS	Fish meal	Soybean meal	Wheat flour	Corn Gluten meal	Shrimp shell meal	Squid by-product meal	Squid oil	Lecithin	Vitamin premix	Mineral premix	Anti-mold & Anti-oxidant
Protein source	+++	++	(+)	++	++	++					
Energy source	++	+	++			++	+++	+++			
Lipid source	++				+	++	+++	+++			
Unsaturated fatty acids	++				+	+	+++	+			
Phospholipids	+				+	+	+	+++			
Cholesterol	+				++	++	++				
Vitamin source	(+)								+++		
Mineral source	+				+					+++	
Growth promotors						(+)					
Pigment source				+	(+)				(+)		
Attractant	++				++	+++	+++				
Binder (waterstability)		-	++		-						
Improving preservation											+++

Legend: + indicates positive effect, - indicates negative effect

Nutrient composition of Selected Protein sources in *L.vannamei*

Component or amino acid	FM[a]	BM[b]	MBM[c]	PBM[c]	SHM[c]	SVM[c]	SBM[b]	RM[b]	CM[b]	PM[b]	CGM[b]	BY[b]
Proximate composition												
Dry matter (g/kg)	926	931	949	955	962	868	927	912	933	940	951	916
Crude protein (g/kg)	623	779	565	511	371	406	474	366	459	462	603	380
Crude lipid (g/kg)	58	7	137	178	17	159	12	30	15	77	21	40
Ash (g/kg)	223	109	216	226	453	66	60	77	121	129	17	48
Crude fiber (g/kg)	5	3	28	26	119	90	56	125	118	63	25	8
Nitrogen-free extract (g/kg)	17	33	3	14	2	147	325	314	220	209	285	440
Gross energy (MJ/kg)	18.6	19.5	20.5	19.7	12.2	20.1	18.2	17.4	17.3	18.7	20.4	18.3
Phosphorus (g/kg)	40	6	36	38	16	6	9	13	12	9	6	8

(FM = fish meal; BM = blood meal; MBM = meat-and-bone meal; PBM = poultry byproduct meal; SHM = shrimp head meal; SVM = squid visceral meal; SBM = soybean meal; RM = rapeseed meal; CM = cottonseed meal; PM = peanut meal; CGM = corn gluten meal; BY = brewer's yeast).

Denghang Yu et al.,

Apparent Nutrient Digestibility of Selected Protein sources in *L.vannamei*

TABLE 3. Apparent digestibility coefficients (ADC;%) of dry matter (DM), crude protein (CP), crude lipid (CL), gross energy (GE), and phosphorus (P) in the tested ingredients (acronyms defined in Table 2) for Pacific white shrimp. Values from each treatment are means ± SD of triplicate tanks. Within a given column, values with differing letters are significantly different ($P < 0.05$).

Test ingredient	ADC_{DM}	ADC_{CP}	ADC_{CL}	ADC_{GE}	ADC_{P}
FM	87.0 ± 1.3 u	90.9 ± 1.9 ut	92.5 ± 1.2 t	97.2 ± 0.9 t	79.9 ± 1.7 v
BM	55.2 ± 1.0 x	69.1 ± 1.7 y	70.2 ± 1.4 xw	57.5 ± 1.1 y	52.1 ± 2.0 z
MBM	76.5 ± 2.3 v	82.2 ± 2.5 w	68.1 ± 1.5 x	82.3 ± 1.7 u	72.7 ± 2.2 w
PBM	72.0 ± 1.6 w	83.9 ± 2.1 wv	66.8 ± 1.6 x	84.0 ± 1.2 u	72.5 ± 1.4 w
SHM	50.5 ± 1.7 zy	78.9 ± 2.0 x	2.1 ± 1.6 z	63.0 ± 1.7 y	53.5 ± 2.3 z
SVM	51.6 ± 1.1 zy	70.9 ± 1.5 y	85.5 ± 0.8 u	66.8 ± 1.0 w	59.1 ± 1.8 y
SBM	71.7 ± 0.4 w	92.3 ± 0.9 t	75.2 ± 2.9 wv	83.0 ± 0.4 u	67.8 ± 2.2 x
RM	50.8 ± 1.9 zy	78.3 ± 1.5 x	54.3 ± 1.0 y	65.6 ± 1.2 xw	61.5 ± 1.5 y
CM	49.9 ± 1.1 zy	57.6 ± 1.2 z	53.6 ± 1.0 y	63.8 ± 0.9 x	58.6 ± 2.2 y
PM	53.2 ± 3.7 yx	88.8 ± 1.7 vu	77.8 ± 1.3 v	72.0 ± 2.2 v	61.8 ± 2.6 y
CGM	48.6 ± 1.1 z	55.7 ± 0.9 z	67.3 ± 2.3 x	51.1 ± 0.9 z	63.7 ± 2.1 yx
BY	71.7 ± 2.2 w	85.7 ± 2.1 v	72.1 ± 2.3 w	84.6 ± 0.8 u	78.5 ± 2.0 v

(FM = fish meal; BM = blood meal; MBM = meat-and-bone meal; PBM = poultry byproduct meal; SHM = shrimp head meal; SVM = squid visceral meal; SBM = soybean meal; RM = rapeseed meal; CM = cottonseed meal; PM = peanut meal; CGM = corn gluten meal; BY = brewer's yeast).

Denghang Yu et al.,

Why use Fish Meal ?

Importance of marine protein meal and marine oils

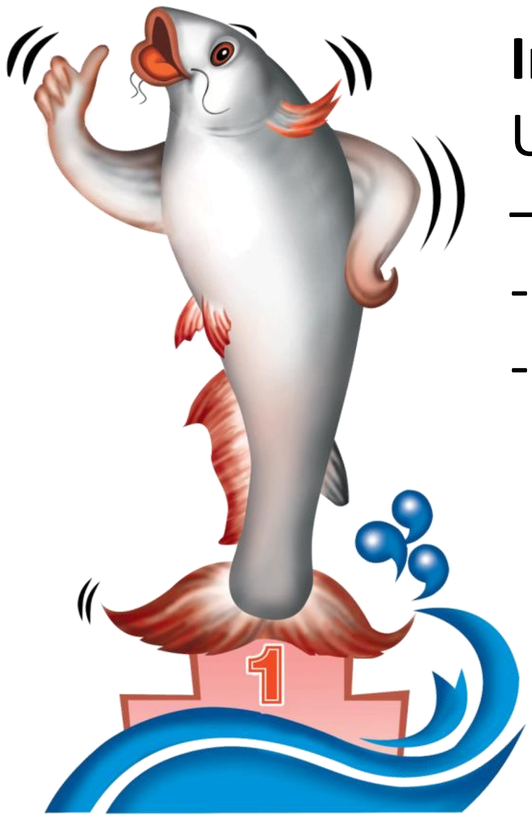
Most aquaculture feed formulation relies heavily on marine protein sources (fish meal, squid and shrimp products)

Marine protein sources provide a wider range of essential nutrients than plant or land animal protein sources:

Specific essential amino acids
Essential poly-unsaturated fatty acids
Cholesterol
Phospholipids
Minerals
Attractants
Other known and unknown growth factors.

IT IS VERY DIGESTIBLE – NUTRIENTS AVAILABLE TO SHRIMPS

What goes into fish and shrimp feeds?



Ingredients selected must not have

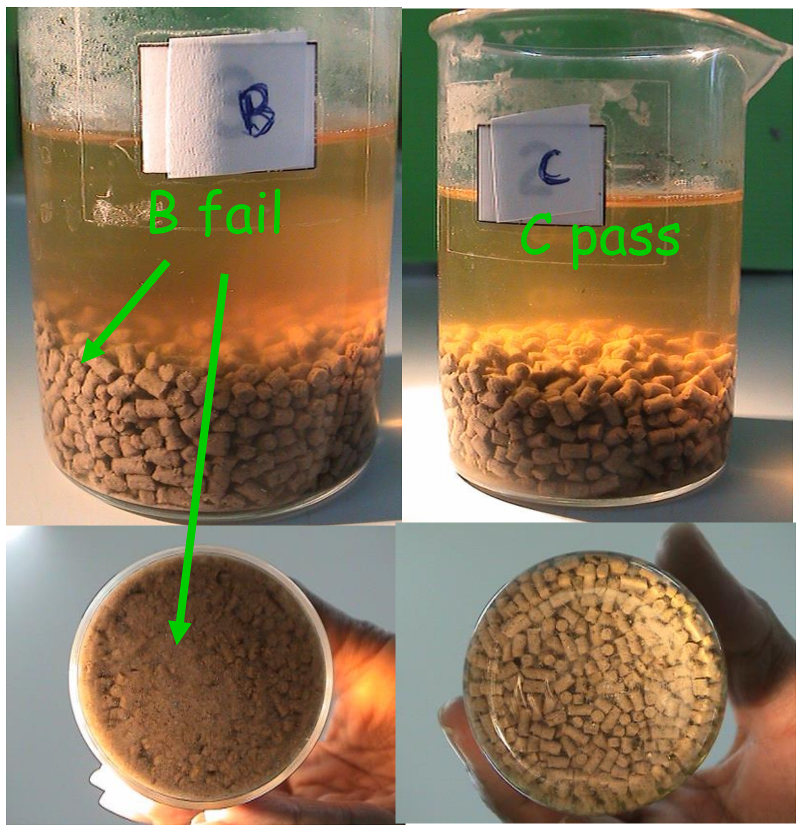
Undesirable components and contaminants

– melamine
- antibiotics residues
- heavy metals

Physical quality criteria

- Water stability
- Fines/Dust
- Color
- Smell

Water stability: 3 h check



Water stability – Shrimp feeds

- **Finding the right balance:**

  - If too low: more essential nutrients leach out, higher % of the feed is unconsumed leading to high FCR and water pollution

  - If too high: lower digestibility, less eaten by shrimp, uneaten feed more difficult to dissolve and degrade by microbial flora leading to anoxic pond bottom

Feed quality parameters

- High fines (<250 microns)
  - Wasted feed, pollution
- Smell
  - Too strong smell may indicate lower raw material quality and high % NH3 leading to faster water pollution
  - Too low smell may indicate high plant protein content
  - Fresh, clean smell is important: watch out for rancid smell, moldy smell, burnt smell, ammonia smell

  - Human smell different from shrimp smell

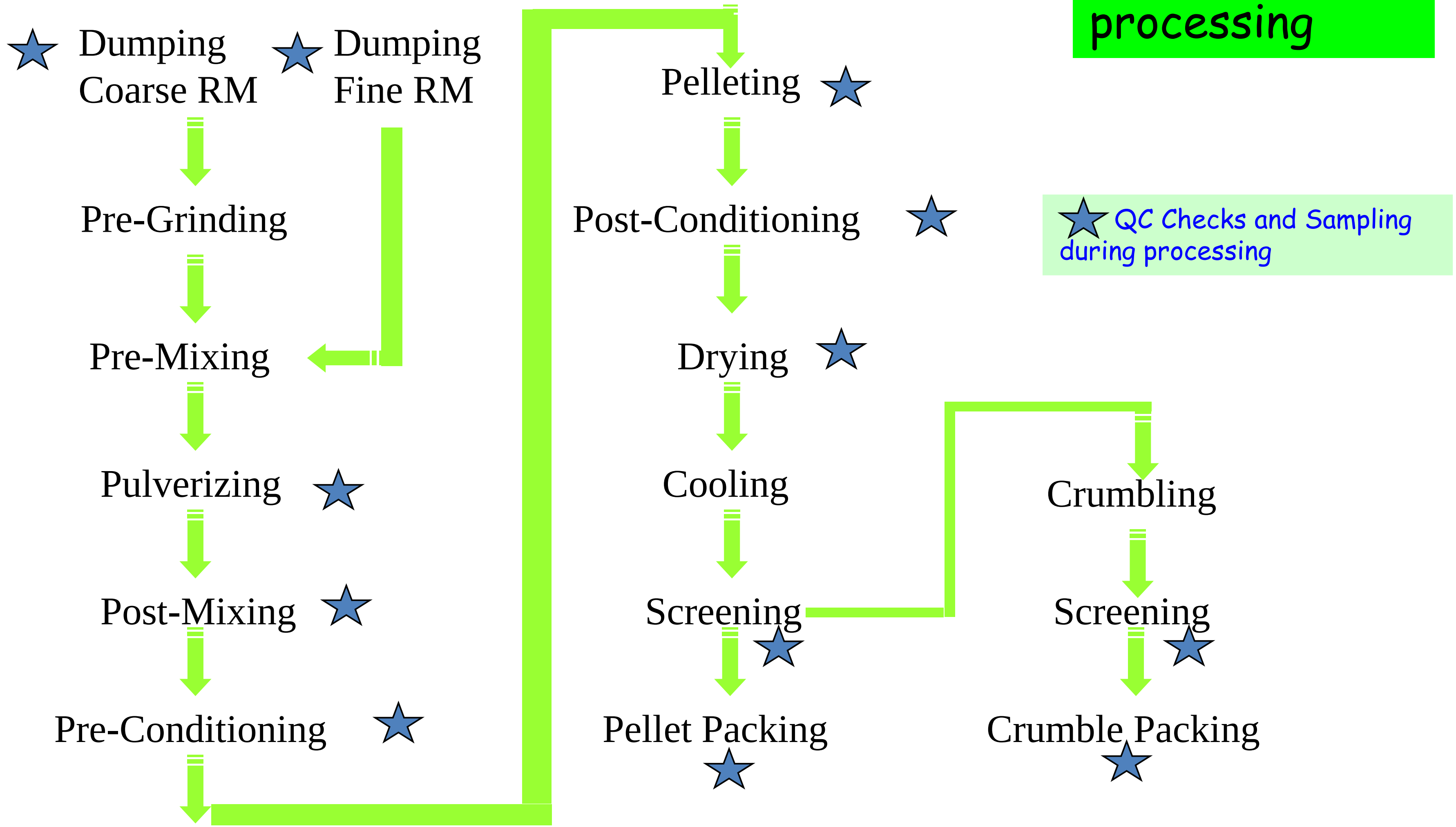
Feed quality parameters

Color

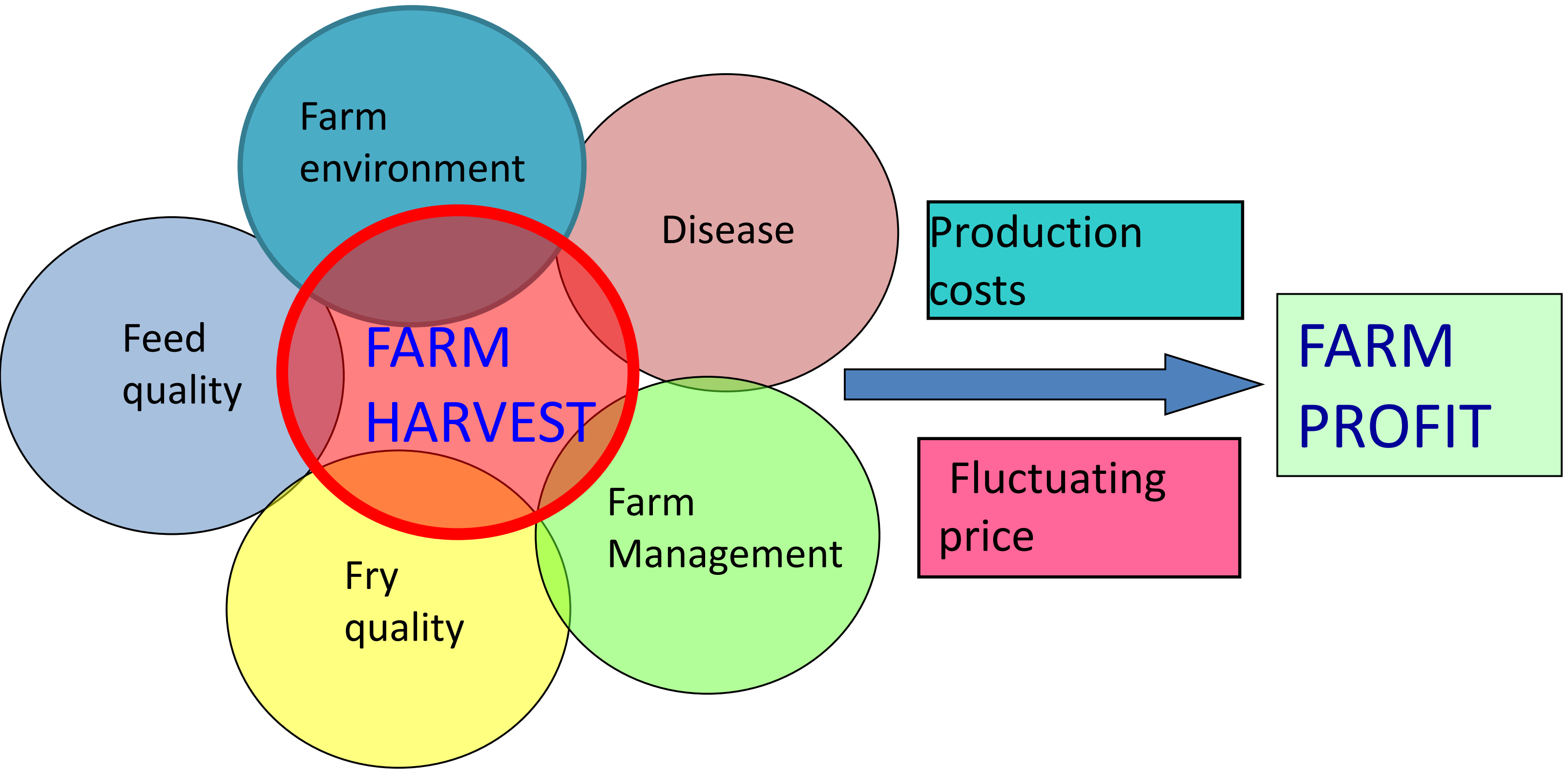
- Color affected by type and color of raw materials
- Even Anchovy fish meal, I.e. from the same fish species, can have color variations.
- Color per se is less important than color homogeneity.
- Color variation within pellets can indicate insufficient mixing.




Shrimp feed processing

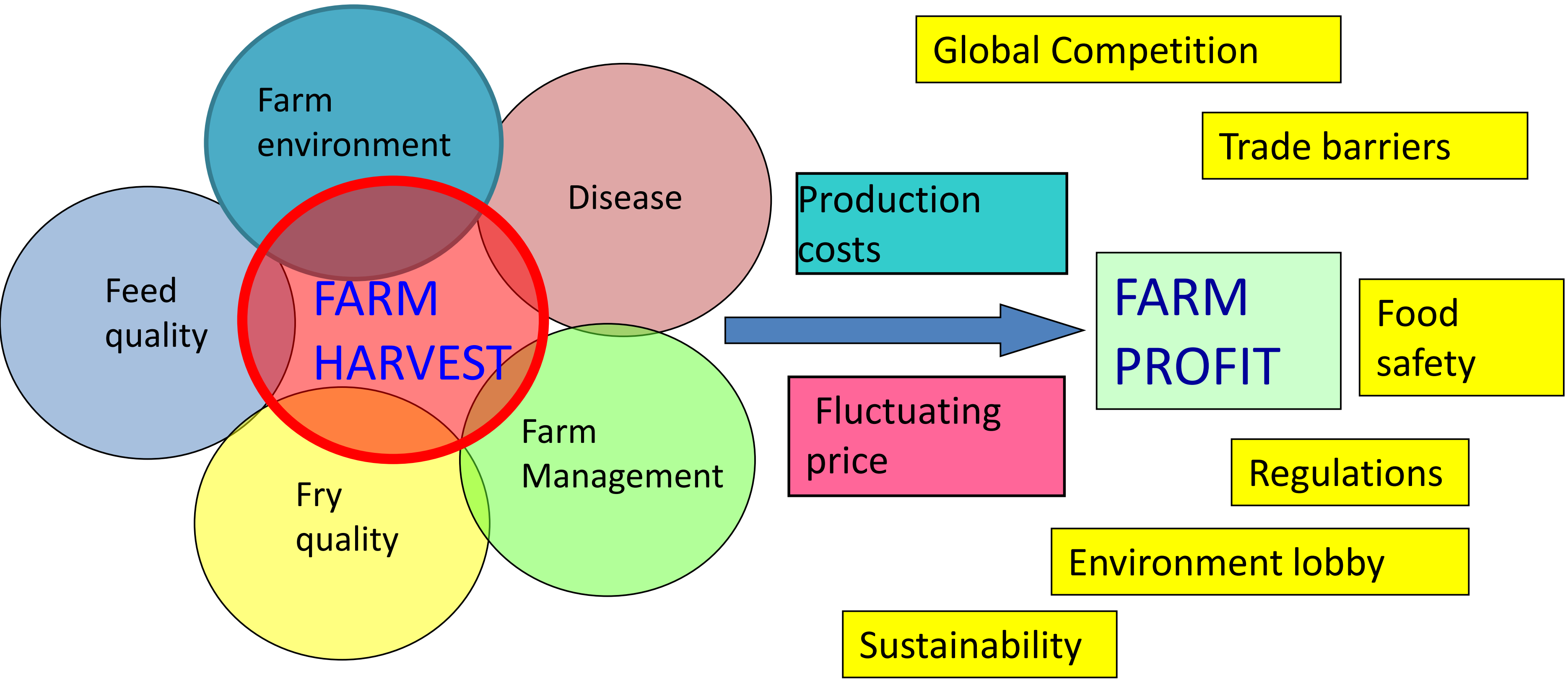


Old Challenges



Old Challenges

New Challenges



Aquaculturists today face new challenges of increasing complexity

Intensive farming system challenges

Intensive shrimp farming

High Biomass

High level of feed

Water use

Competition
Space
Feed

Solid wastes
Uneaten feed,
Undigested feeds
Faeces

Water quality deterioration

Pond bottom deterioration

Stress

Impaired immunity

Disease – lower survival

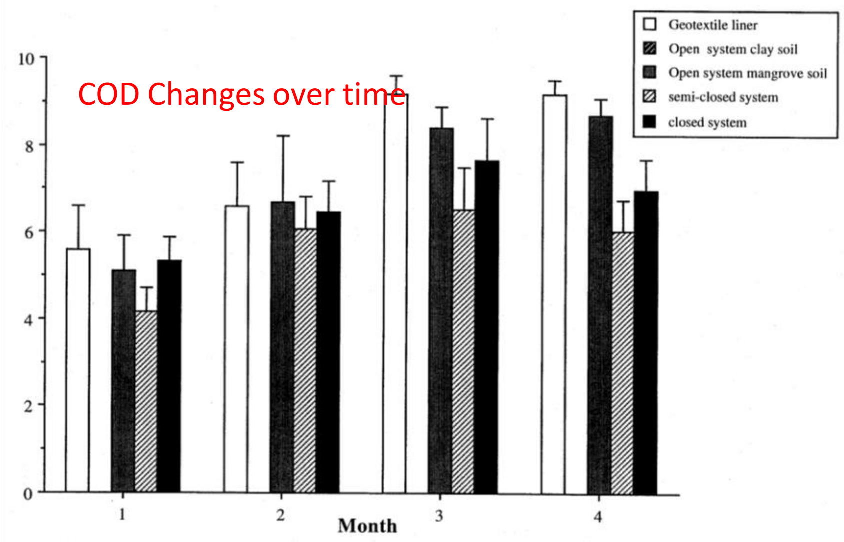
Poor growth

Poor FCR

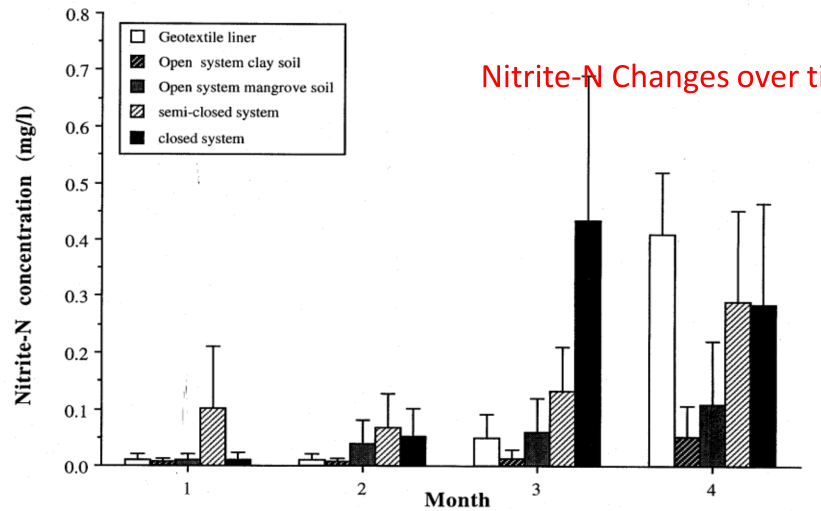
Lower productivity

Pond water quality during production

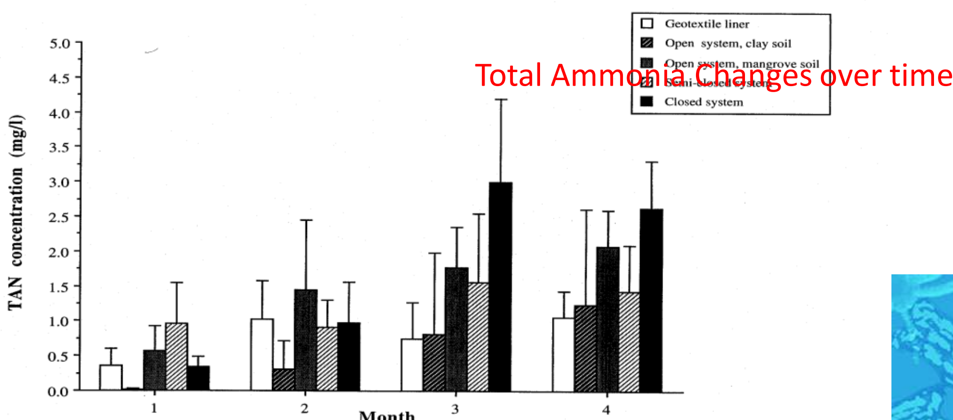
Pondwater Chemical Oxygen Demand during production from different types of intensive shrimp ponds in southern Thailand



Pondwater Nitrite-N concentrations during production from different types of intensive shrimp ponds in southern Thailand



Pondwater TAN concentrations during production from different types of intensive shrimp ponds in southern Thailand



Species: *P. monodon*

Stocking density – 60 - 100PL/m2

SJ Funge-Smith - 1996

Pond water quality during production

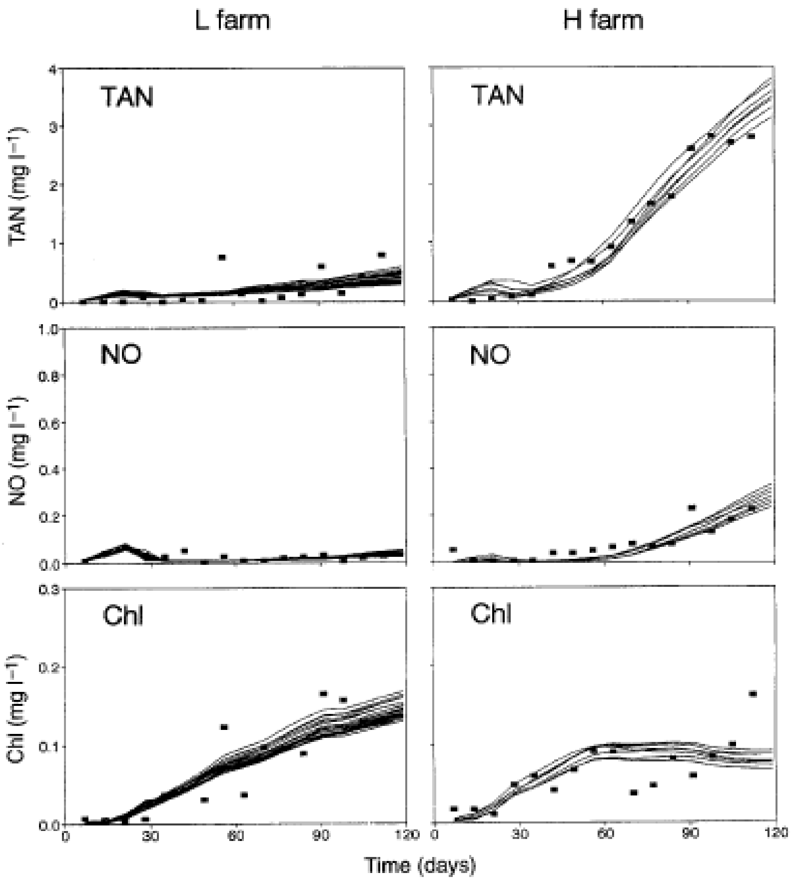


Figure 3 Model predictions (lines) and observed values (solid squares) of total ammonia nitrogen (TAN), nitrite/nitrate (NO) and chlorophyll (Chl) over the course of production cycles in the low-intensity L and high-intensity H farms. Each line represents predictions from one of the identified parameter sets.

Species: *P. monodon*

Low stocking density
- 48 PL/m2
- 4 t/ha/cycle

High stocking density
- 98 PL/m2
– 9t/ha/cycle

Water exchange programme 0.4%, 4%, 6% , 8% per day in the 1st, 2nd,3rd and 4th month respectively.

Lorenzen and Struve, 1997

Stress and energy requirement

Total haemocyte count (THC) of *L.vannamei* after exposure to nitrite stress

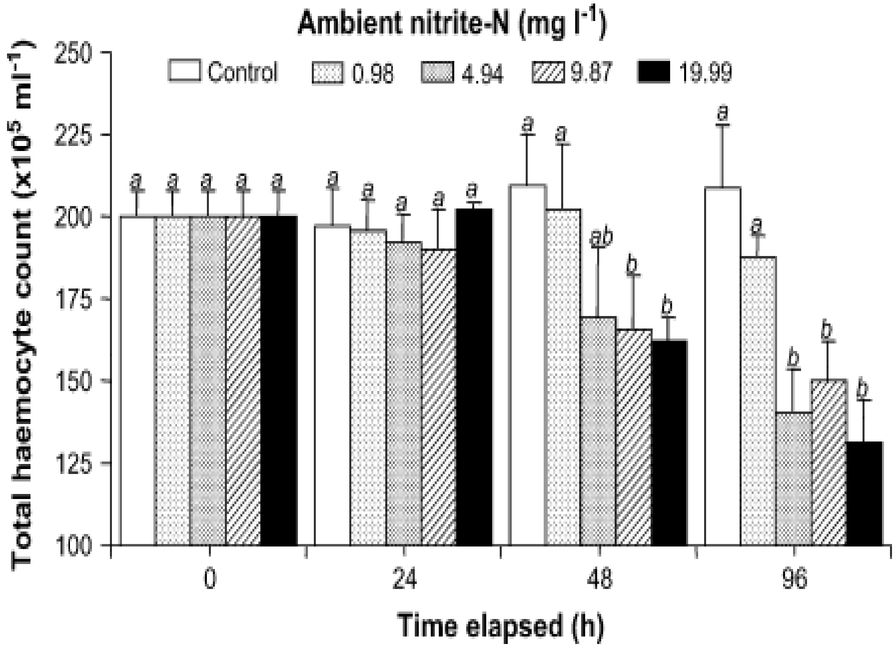


Fig. 1. Mean (+SE) total haemocyte count (THC) of *Litopenaeus vannamei* after 24, 48 and 96 h exposure to different concentrations of nitrite-N. Each bar represents mean value from eight determinations with standard error. Data in the same exposure time with different letters are significantly different ($P < 0.05$) among treatments.

SJ Funge-Smith - 1996

Stress and energy requirement

Exposure to high level of NH_3 affects osmoregulation (Lin et.al, 1993) and inducing an increase energy expenditure associated with processes involved with ionic and osmotic regulation (Chen et al, 1993)

Feed intake is negatively impacted by exposure to high NH_3 (Miranda-Filho et al, 2009), affecting availability of dietary energy.

Stress and energy requirement

- Low oxygen levels in ponds were found to reduce immune defense in *Litopenaeus stylirostris* and *P. monodon* and increase susceptibility to infectious diseases (Le Moullac et al., 1998).
- Oxygen and aeration were major factors in the dynamics of intensive production of *L. vannamei*. High concentrations of oxygen led to larger harvested shrimp and increased biomass by reducing mortality from WSSV (Ruiz-Velazco et al., 2010b; McGraw et al. (2001),)

Stress and energy requirement

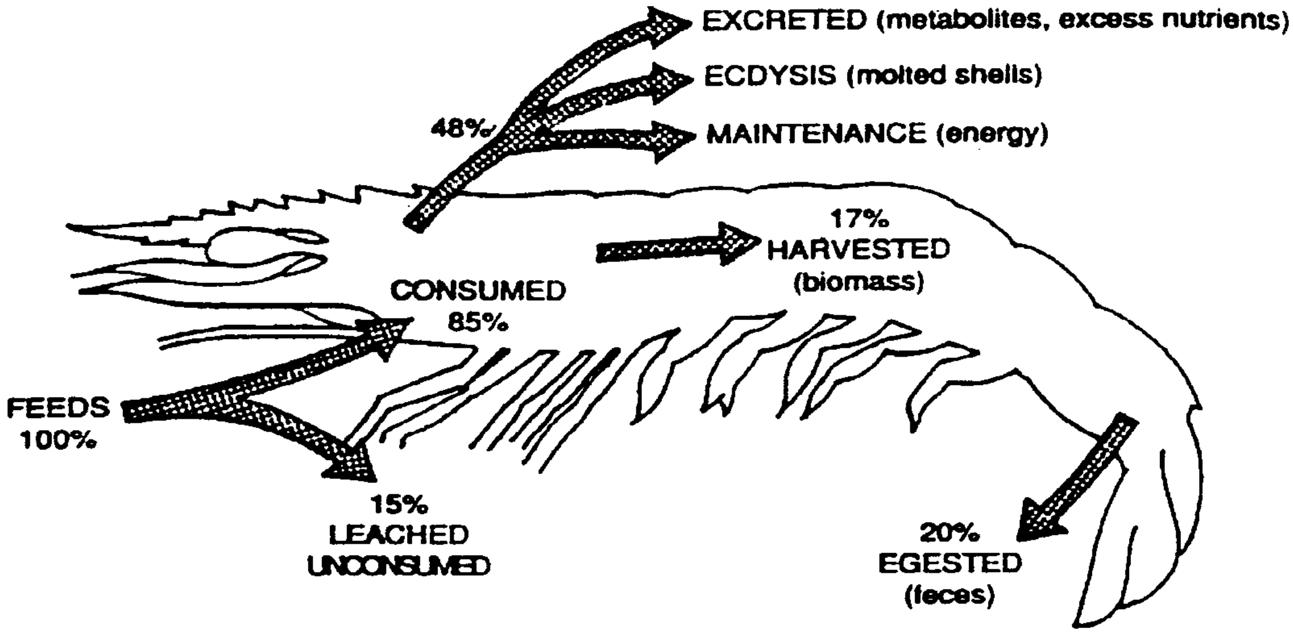
To maintain productivity, it is necessary to reduce the impact of stress and its effects, requiring additional energy and/or other micronutrients over and above those required for growth under normal culture environment.

Energy Balance in aquatic animals

$$C = P + R + U + F + E$$

C= Consumption-gross energy of food consumed
P= Production - energy utilised in growth materials
R= Respiration - net loss of energy as heat during metabolism
U= Urine -energy lost in nitrogenous excretory products
F= Faeces - energy lost in the faeces
E= Exuviae - energy lost in loss of mucus, skin or exoskeleton (during moulting)

Energy Balance in Shrimp



Fate of feeds released in intensive shrimp ponds, based on diet digestibility and food conversion ratios (from Primavera 1994).

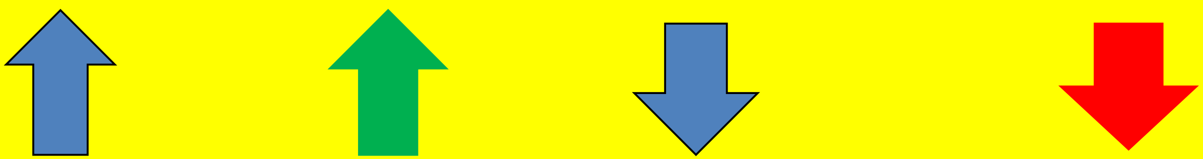
Energy Balance in Shrimp

$$100C = 20P + 56R + 24(U + F + E)$$

NOTE: This equation is valid only for a specified set of conditions. Changes in conditions will result in a different equation.

Energy Balance in Shrimp

$$100C = 20P + 56R + 24(U + F + E)$$



Improvement in feeds - Nutritional

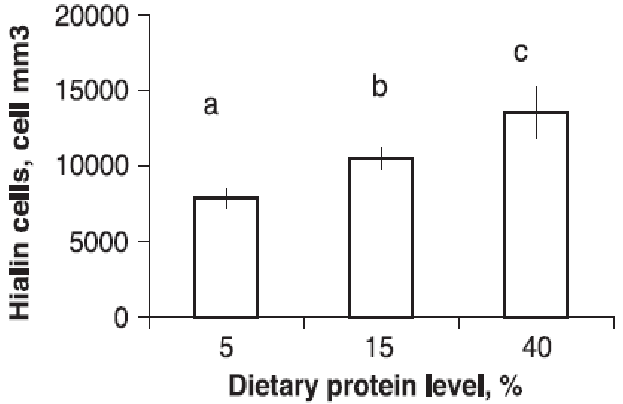
A – Increase availability of dietary energy level in feed

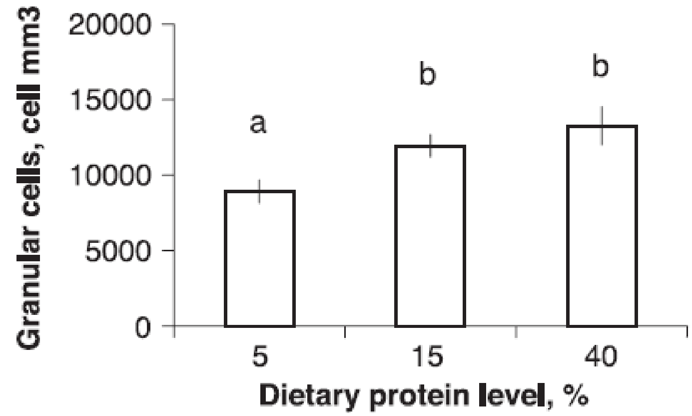
- select appropriate macro nutrient source
- use ingredients which are more digestible

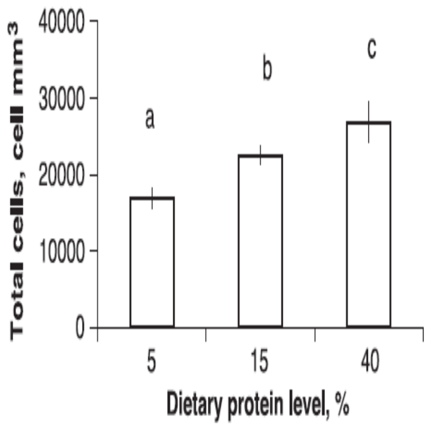
Improvement in feeds- Nutritional

Case for increasing available protein level in feed

- Hemocyanin is related to immune function (as measured by respiratory burst, phagocytic activity, hemocyte concentration) as well as a nutrient and protein source. – Pascual et al. 2004).
- Amount of hemocyanin (oxy-hemocyanin) produced is directly related to dietary protein level.







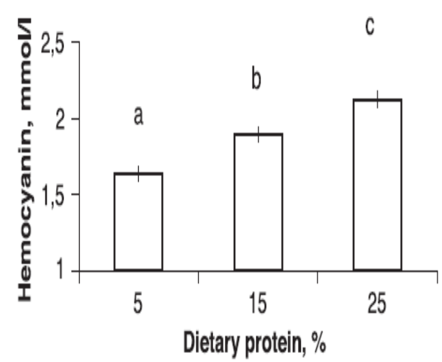


Fig. 5. Effect of dietary protein level (%) on total and differentiated hemocytes of *L. vannamei* fed during 50 days. Mean ± S.E. Different letters denote statistical difference between treatments.

Fig. 3. Effect of dietary protein level (%) on oxyhemocyanin of *L. vannamei* fed during 50 days. Mean ± S.E. Different letters denote statistical difference between treatments.

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Pascual et al 2004

Improvement in feeds- Nutritional

Case for increasing protein level in feed

- Dietary protein level allows prawns to withstand longer periods of starvation without modifying immune responses, than those fed low protein feeds (Pascual et al. (2006)

- Shrimp fed high protein diet were more metabolically efficient and therefore used less energy to maintain routine metabolic rate when compared to shrimp fed a lower protein diet – hence more energy available for growth (Pascual et al., 2004)

Case for increasing protein level in feed

Optimal feed can halve salmon mortality rate

Research by Nofima into outbreaks of the salmon diseases PD (pancreas disease) and HSMB (heart and skeletal muscle inflammation) has shown that mortality can be halved through the optimum use of feed.

They noted that salmon fed on a lean, protein-rich test feed had a mortality rate of 4 per cent. Salmon fed normal control feed with a higher fat content had a mortality rate of 9 per cent. The group fed on the lean test feed also had higher feed intake and growth.

Statistical analysis confirmed that there was lower mortality in large fish, and in fish that were less stressed during handling.

Improvement in feeds- Nutritional

A – Increase availability of dietary energy level in feed

- increase biological availability of energy - use ingredients which are more digestible

Importance of marine protein meal and marine oils

Most aquaculture feed formulation relies heavily on marine protein sources (fish meal, squid and shrimp by-products).

Marine protein sources provide a wider range of essential nutrients than plant or land animal protein sources:

Specific essential amino acids

Essential poly-unsaturated fatty acids

Cholesterol

Phospholipids

Minerals

Attractants

Other known and unknown growth factors.

Improvement in feeds- Additives

B – increase inclusion rate of micronutrients related to immune competency

- vitamin E (Lee and Shiau, 2004)
- vitamin C (Lopez et al.2003)
- Zinc (Shiau and Jiang, 2006)
- selenium (Chiu et al., 2010)

Improvement in feeds- Additives

C – use of immunostimulatory compounds

- chitin and chitosan (Wang and Chen, 2005),
- polysaccharides,– glucan and mannan (Song and Huang, 1999),
- herbs (Citarasu et al., 2006; Yin et al. 2009)
- oil from single celled (thraustochytrid)- (Nonwachai et al., 2010), PUFA (Mercier et al., 2009)
- probiotics (van Hai and Ravi, 2010; O'Brine 2010; Ninawe and Slevin, 2009)

Reduce waste

Cost of feed vs Cost-effectiveness of feeds