Adaptation of Feed Composition and Nutritional Specifications to Production Systems Types and Intensity in Aquaculture

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Optimal Nutritional Specifications

- Aquaculture species can perform equally well on feeds of different compositions
  - There are 1000s of different ways of producing 1 kg of fish
- "Optimal nutritional specifications" may vary as a function of several factors
  - Production system type
  - Intensity of production
  - Socio-economic conditions
- Finding this optimal composition is generally achieve through a "trial and error" process but can/should first be approached scientific manner

  Step 1: Understand some of the basics / underlying issues and processes
  - Step 2: Adopt a systematic approach of adapting the composition

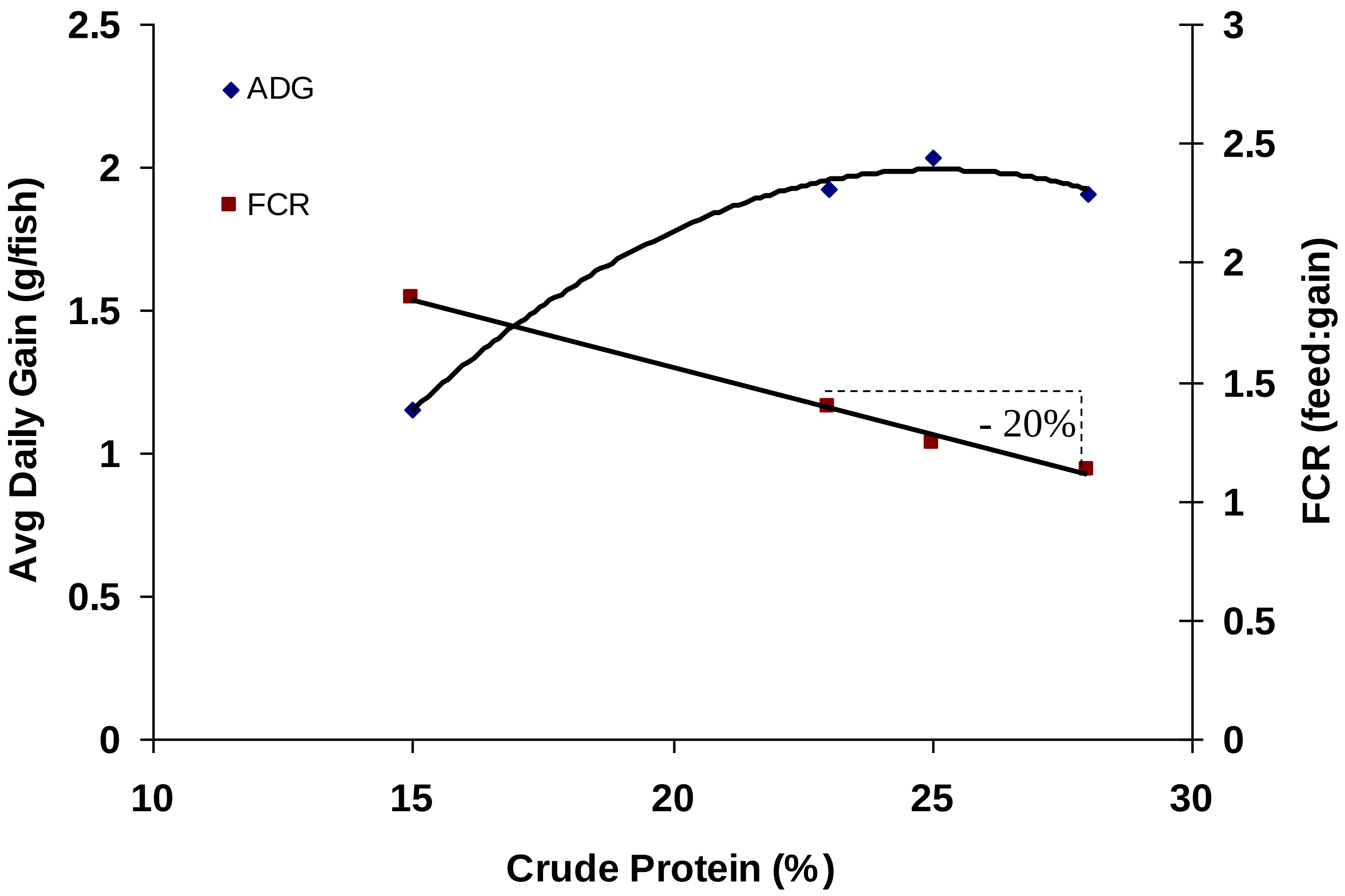
Feed Composition and Fish Performance

Atlantic salmon (Azevedo, 1998)

	Regular	HND
DP, %	37	44
DE, MJ/kg	18	22
DP/DE, g/MJ	20	20
Weight gain, g/fish	33.4	33.6
Feed efficiency, G:F	1.09	1.33
FCR, F:G	0.92	0.75

Take home message: Different feeds can give the same growth, FCR will be what varies between feeds

Daily Weight Gain and Feed Conversion Ratio of Nile Tilapia Fed Commercial Feeds with Different Nutrient Densities



Data from a commercial cage culture operation in SE Asia

Production System Types

- Environment:
  - Fresh vs. brackish vs. marine water
  - Land-based vs. near-shore vs. offshore
  - Outdoor vs. indoor
  - Open vs. semi-closed vs. closed systems

- Pond (earthen, lined-eathern pond, concrete, PVC tarpaulin, concrete, etc.)
- Cage / netpen / hapas
- In-pond raceway (IPR)
- Tank or raceway
  - Flow-through
  - Semi-recirculated
  - Recirculation Aquaculture Systems (RAS)

Production Systems Intensity

- Extensive
  - Mostly relying on natural food with some feed inputs
  - Low intensity – Low stocking density – Target: Low to moderate growth rate and yield
- Integrated Agriculture – Aquaculture
  - Relying mostly on natural food but feed inputs depends on systems (rice:fish, crab:grass, duck:fish, etc.)
  - Low intensity – Low stocking density – Target: Low to moderate growth rate and yield
- Semi-Intensive
  - Relying mostly on feed inputs but some contributions of natural food
  - Moderate stocking density – Target: Moderate to high growth rate - Moderate yield
- Intensive
  - Relying almost exclusive on feed inputs – very small contribution of natural food (if outdoor)
  - High stocking density – Target: High growth and high yield
- Super-Intensive
  - Relying exclusively on feed inputs
  - Very high stocking density – Target: High growth and very high yield

Different Systems = Different Challenges

- Recirculation Aquaculture Systems
  - Waste Management
    - Need to minimize ammonia, solid organic matter outputs and suspended solids
    - Need to minimize CO_2 outputs and oxygen demand

- Indoor and High Intensity Systems
  - No contribution of natural food
    - Feed need to be nutritional complete

- Outdoor Systems
  - Environmental variations
    - Dramatic variation in water quality parameters (DO, NH_3-N, pH, etc.) and bacterial (incl. pathogen) load

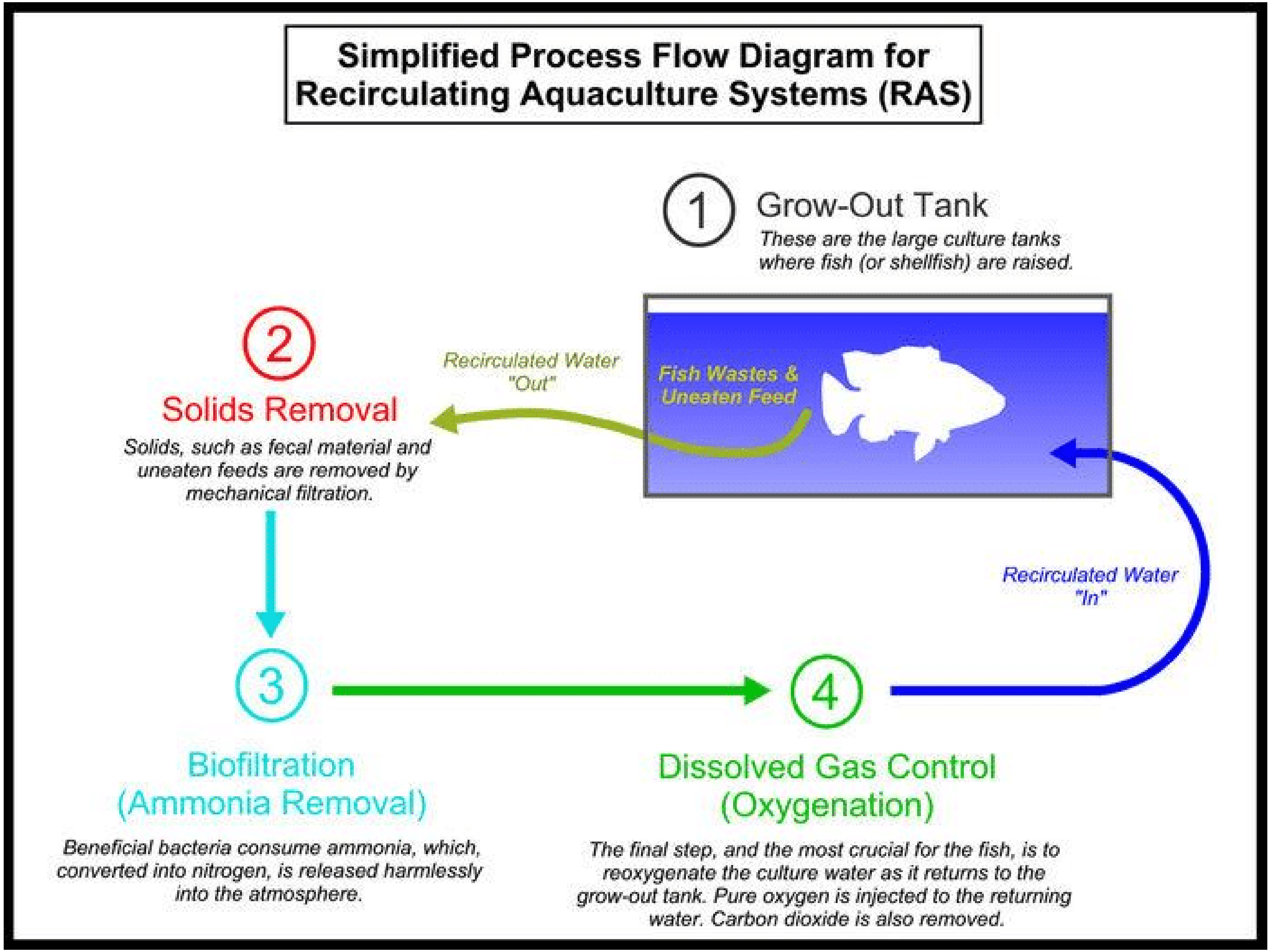
  - Environmental Impacts
    - Need to manage solid, N and P waste outputs

Open FW System Beautiful Scenery, Clean Water, Potential conflicts with recreational use = Solid wastes (manure pile), dissolved phosphorus (eutrophication)

Close System, Muddy Water, Air-Breathing Species = Different sets of constraints (ammonia?)

Semi-Closed SW System =
Constraints = ammonia, DO, solid organic wastes, etc.

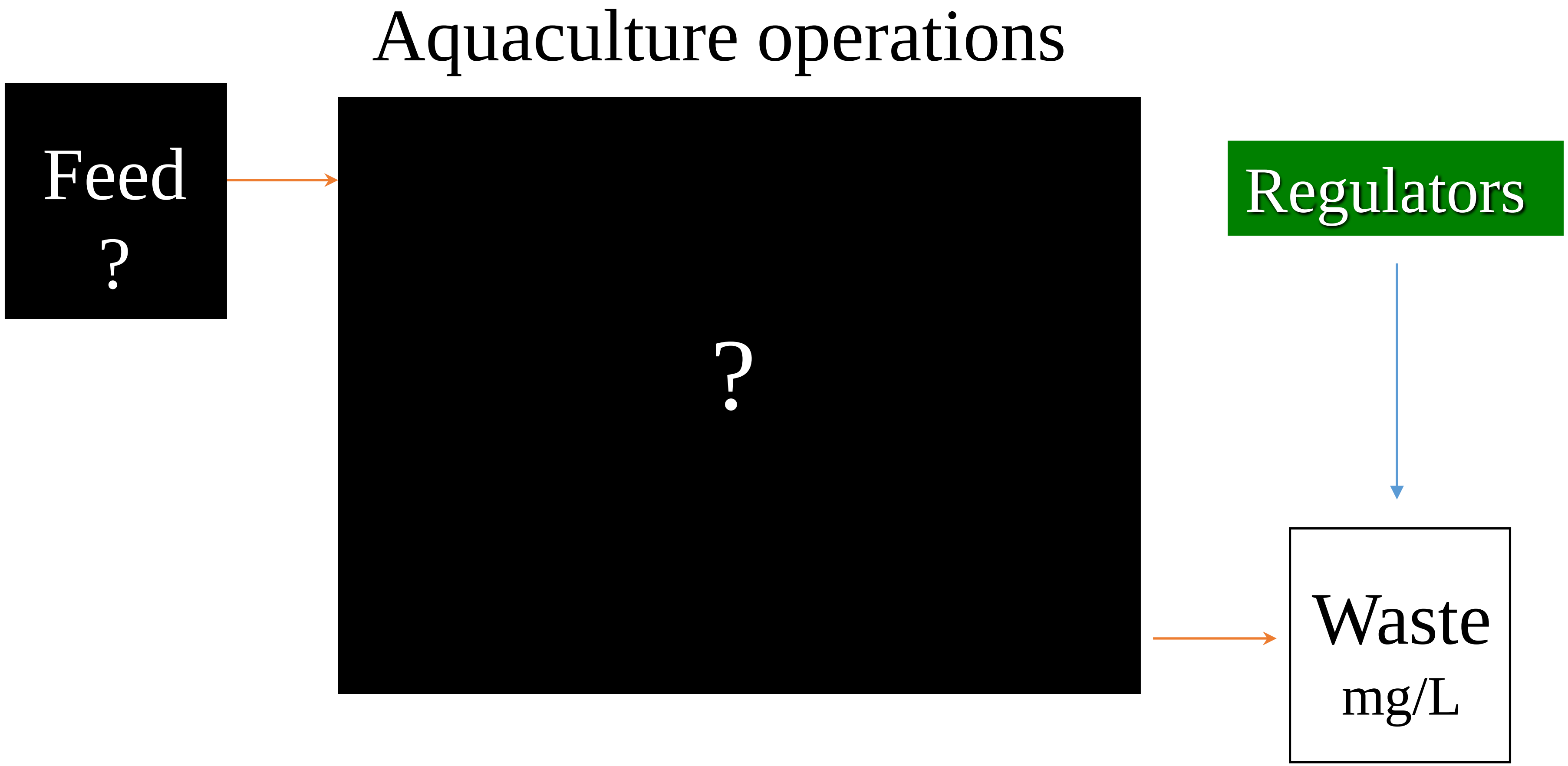
Fully Closed RAS, high density, high cost
Constraints = solid wastes, ammonia, DO, CO_2



Simplified Process Flow Diagram for
Recirculating Aquaculture Systems (RAS)
1 Grow-Out Tank
These are the large culture tanks
where fish (or shellfish) are raised.
Fish Wastes &
Uneaten Feed
Recirculated Water
"Out"
2 Solids Removal
Solids, such as fecal material and
uneaten feeds are removed by
mechanical filtration.
Recirculated Water
"In"
3 Biofiltration
(Ammonia Removal)
Beneficial bacteria consume ammonia, which,
converted into nitrogen, is released harmlessly
into the atmosphere.
4 Dissolved Gas Control
(Oxygenation)
The final step, and the most crucial for the fish, is to
reoxygenate the culture water as it returns to the
grow-out tank. Pure oxygen is injected to the returning
water. Carbon dioxide is also removed.

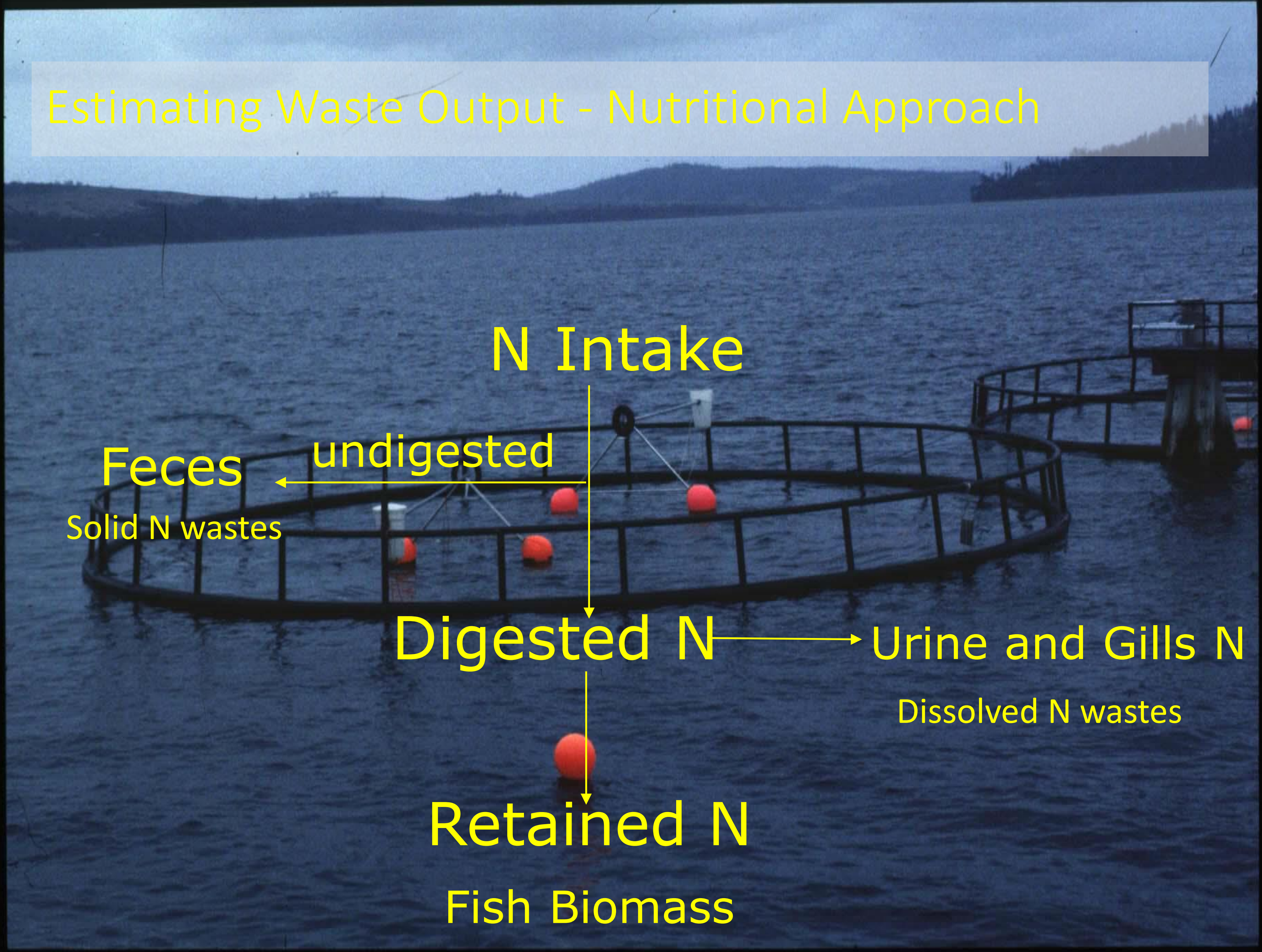
Principles of Nutritional Waste Management

Estimating Waste Outputs - Chemical Approach



"Black-box" approach

Estimating Waste Output - Nutritional Approach



Some Nutritional Principles

- Wastes originate from feed and metabolism

- Feed composition and digestibility and feed requirement (i.e. FCR, feed:gain) determine solid waste (organic, N, P) outputs

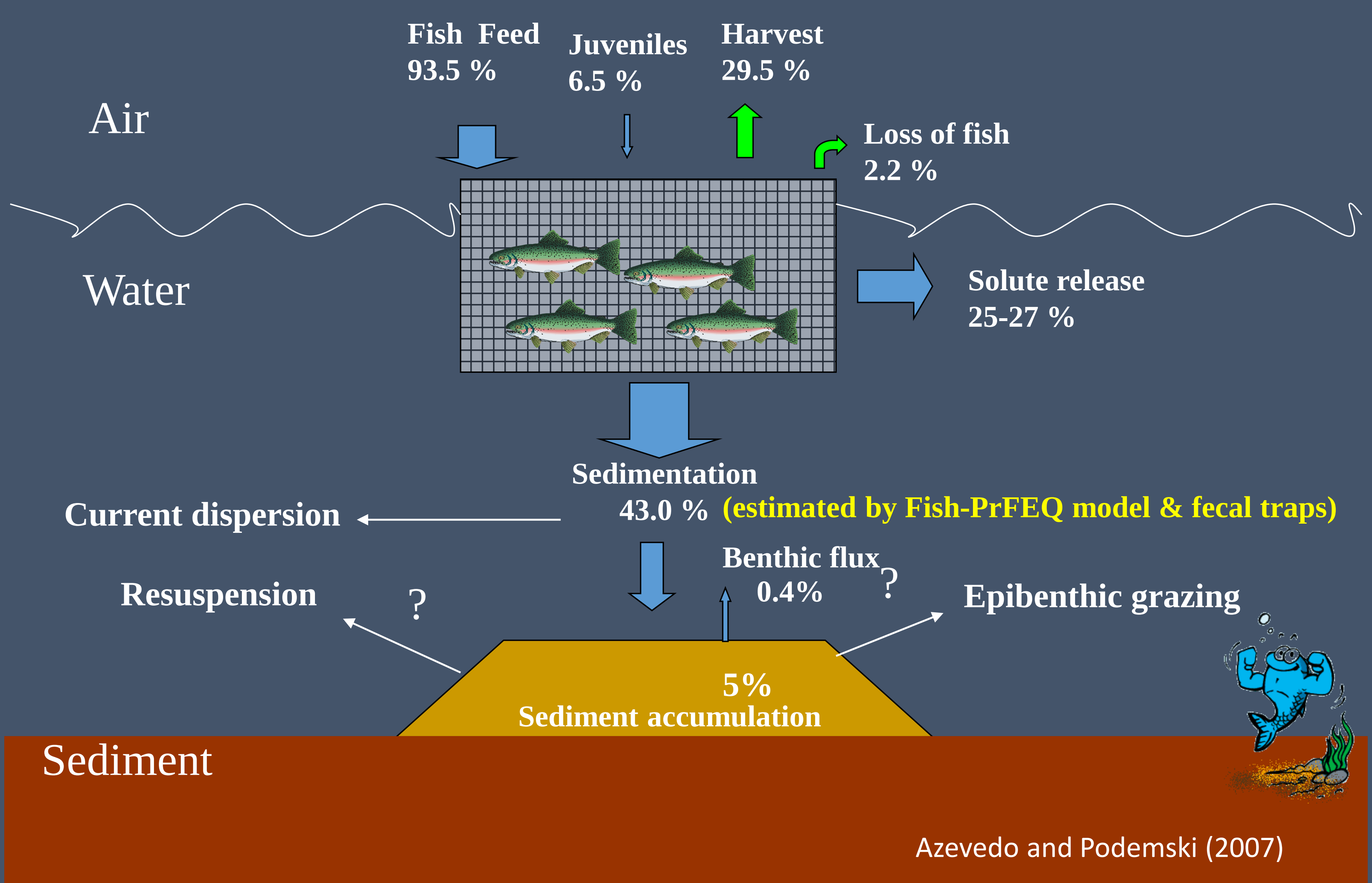
- Digestible nutrient intakes, metabolism (efficiency of nutrient/energy utilization) and environmental processes (e.g. biodegradation) affect dissolved N oxygen requirements and CO_2 outputs

Different types of wastes matter to different aquaculture operations

Wastes	Cage		Pond		RAS
	Fresh	Marine	Fresh	Marine	
Solid	**FW**	**SW**	**FW**	**SW**	
Total	++	++	+	+	++
Organic	+++	+	+++	+++	+++
Nitrogen		+			++
Phosphorus	+				
Dissolved					
Nitrogen		+++	+++	+++	+++
Phosphorus	+++				
CO_2					+++

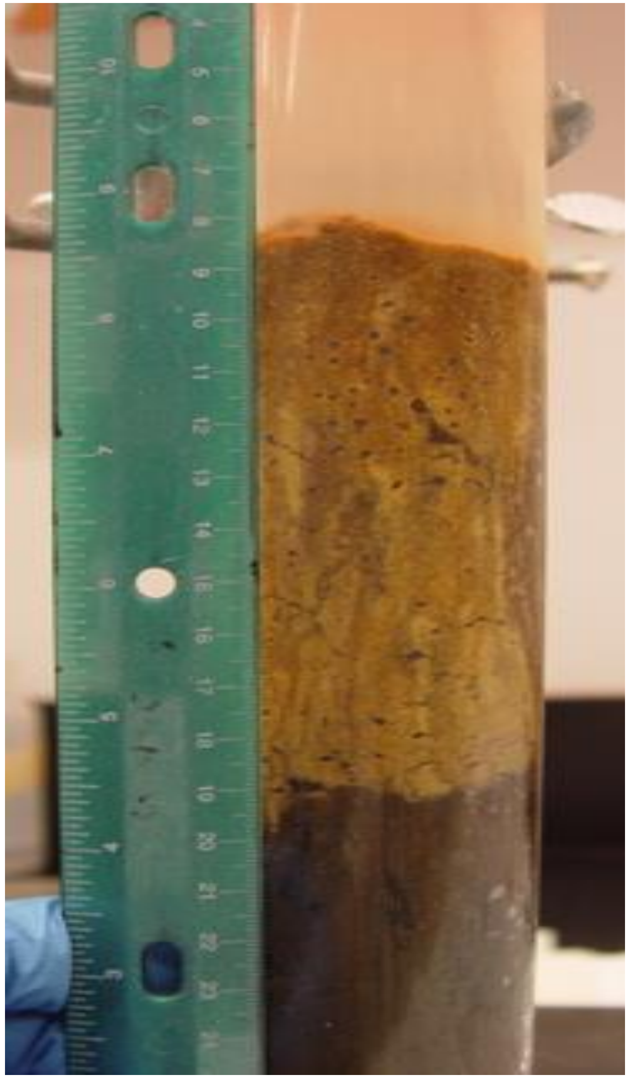
+ moderately important, ++ important, +++ highly important

Phosphorus Mass Balance for Lake 375 in 2005



Azevedo and Podemski (2007)

Parameters	1980's Feed	2000's Feed	Progress achieved
Chemical Composition			
Crude Protein, %	36	44	Digestible nutrient density greatly increased
Lipid (Fat), %	10	24	
Digestible Energy, MJ/kg	14	19	
Phosphorus (P), %	2.5	1.1	
Apparent Digestibility Coefficient (%)[1]			
Dry matter (DM)	65	78	
Crude protein (CP)	85	88	
Gross energy (GE)	70	80	
Phosphorus (P)	50	60	
Theoretical FCR[2] , feed:gain	1.5	1.1	
Total Solid Wastes			
kg / tonne of feed fed	350	220	Reduced to less than half
kg / tonne of fish produced	540	250	
Solid Nitrogen Wastes			
kg / tonne fish produced	13	9	
Solid Phosphorus Wastes			
kg / tonne fish produced	19	5	Reduced to a fourth
Dissolved Nitrogen Wastes			
kg / tonne fish produced	48	43	
Dissolved Phosphorus Wastes			
kg / tonne fish produced	16	4	Reduced to a fourth



Solid Wastes

Ingredients	Apparent digestibility coefficients (%)			
	Dry Matter	Crude Protein	Lipid	Energy
Alfalfa meal	39	87	71	43
Blood meal				
ring-dried	87	85	-	86
spray-dried	91	96	-	92
flame-dried	55	16	-	50
Brewer’s dried yeast	76	91	-	77
Corn yellow	23	95	-	39
Corn gluten feed	23	92		29
Corn gluten meal	80	96	-	83
Corn distiller dried soluble	46	85	71	51
Feather meal	77	77	-	77
Fish meal, herring	85	92	97	91
Meat and bone meal	70	85	-	80
Poultry by-products meal	76	89	-	82
Rapeseed meal	35	77	-	45
Soybean, full-fat, cook.	78	96	94	85
Soybean meal, dehulled	74	96	-	75
Wheat middlings	35	92	-	46
Whey, dehydrated	97	96	-	94
Fish protein concentrate	90	95	-	94
Soy protein concentrate	77	97	-	84

Solid Waste Outputs

Total solid waste output (TSW)=

$$\text{(Feed consumed x } (1\text{-}ADC_{D.M.})) + \text{wasted feed}$$

The higher the digestibility (ADC), the lower the solid waste (SW)

Feed A with ADC dry matter = 75%

produce 25 kg SW per 100 kg DM consumed

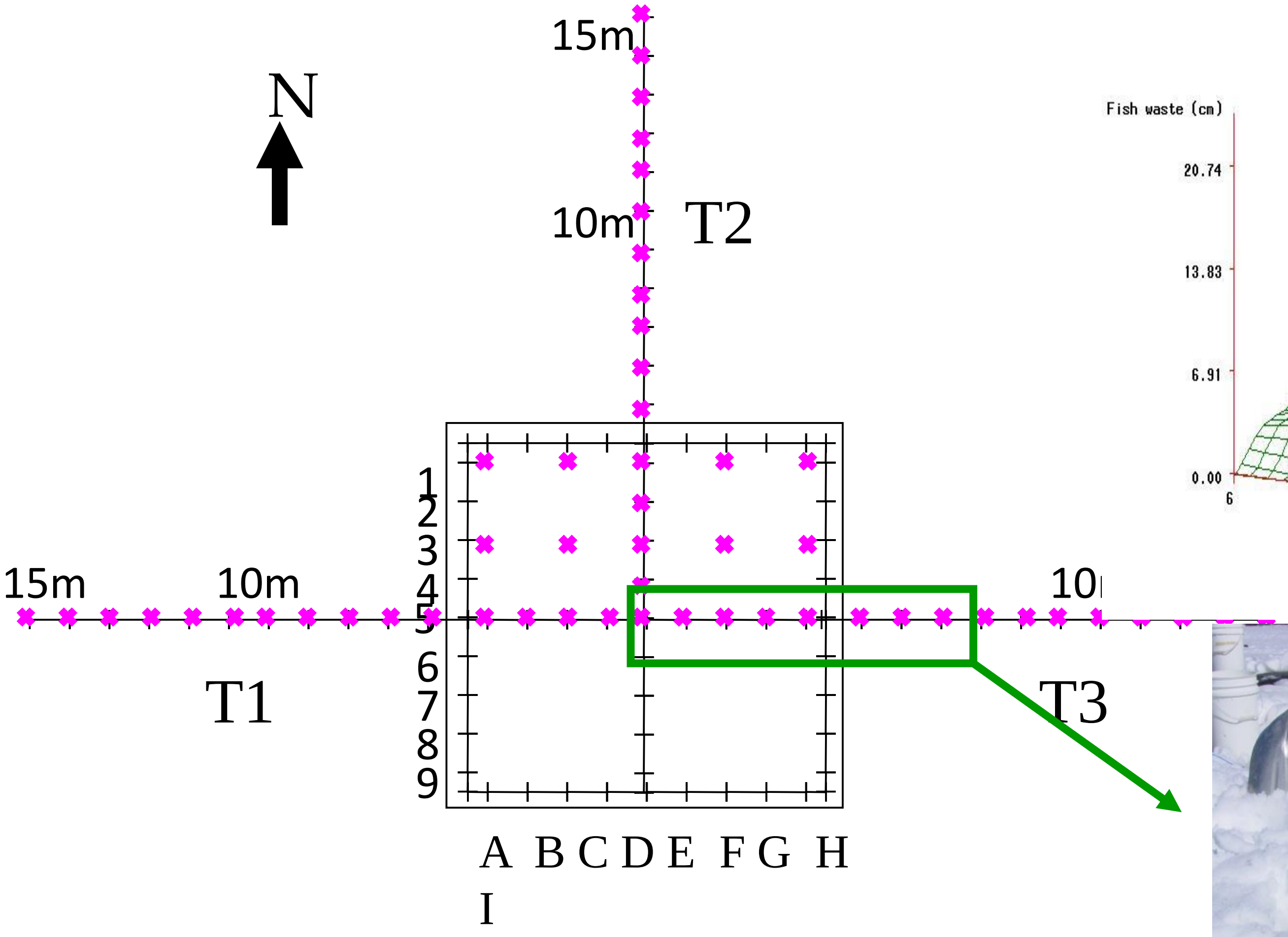
Feed B with ADC dry matter = 80%

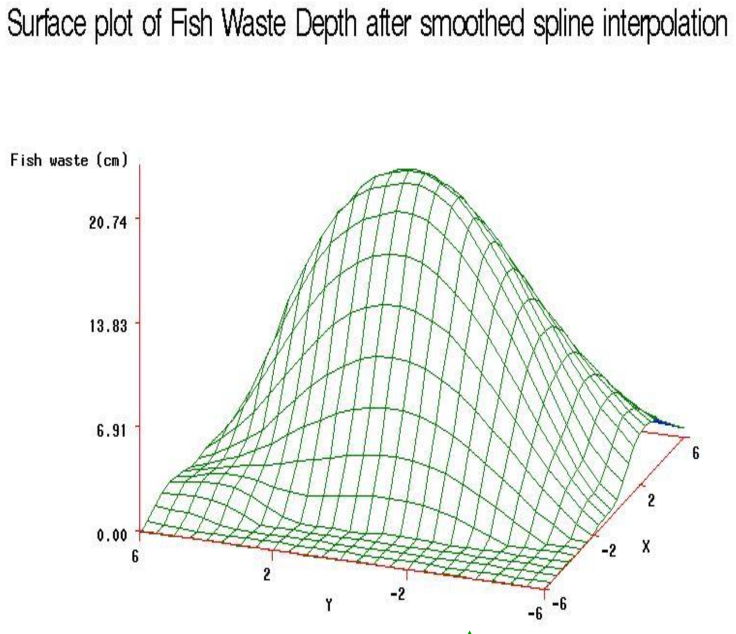
produce 20 kg SW per 100 kg DM consumed

Crude protein (CP), total dietary fiber (TDF) and Fiber-associated solid waste of TDF of various practical feed ingredients

Ingredients	**CP**	**TDF**	**Fiber-Derived Solid Waste**
	%	**%**	**kg/t feed**
Cottonseed meal	28	60	700
Wheat bran	17	42	370
Corn gluten feed	21	38	340
Canola meal	35	28	260
Soybean meal	48	21	190
Corn	8	10	88
Corn gluten meal	60	6	5

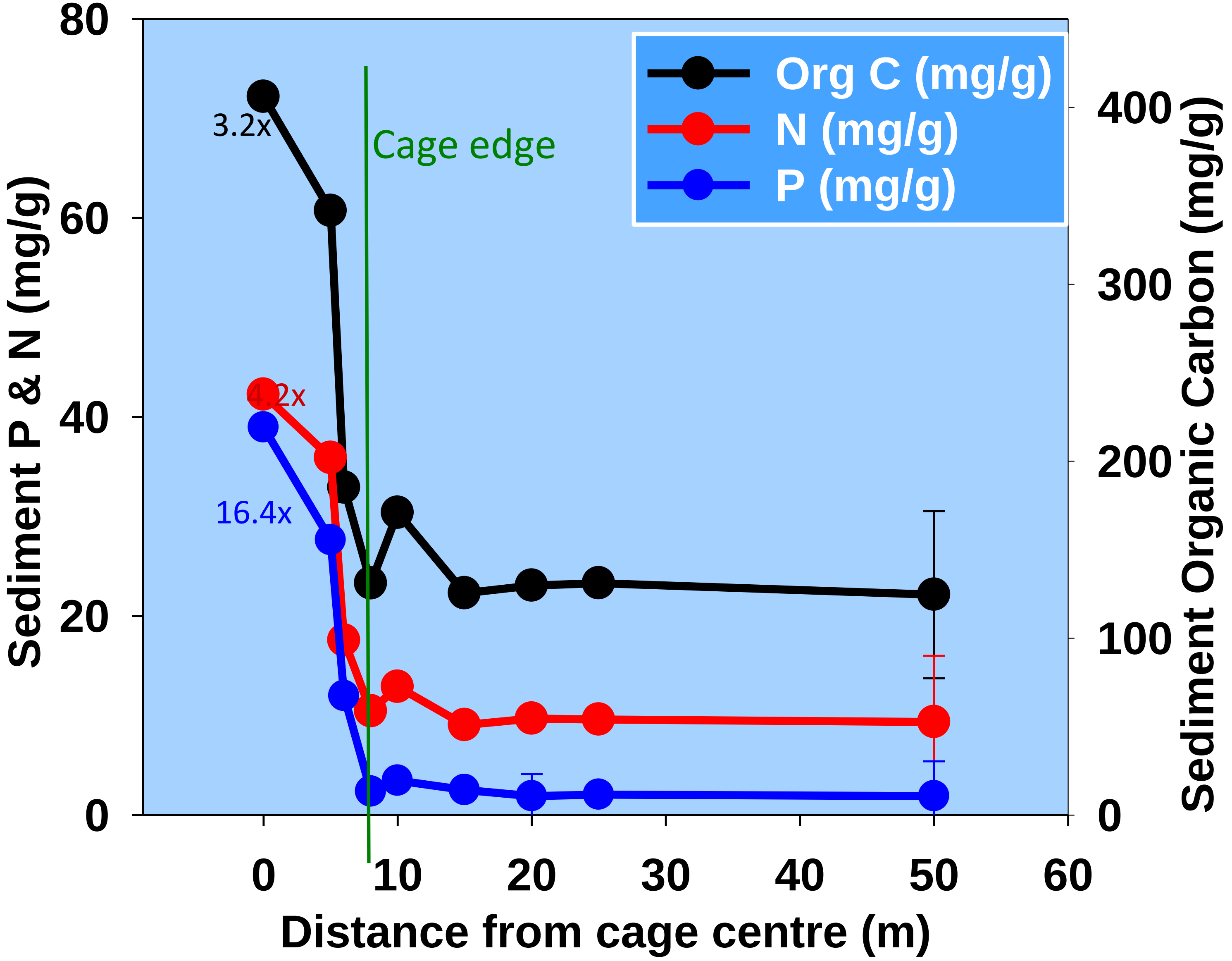
Assessing the Footprint of an Open Water Cage Culture Operation





Podemski and Azevedo (2007)

Sept 2004



C. Podemski

Feces Physico-chemical Characteristics?

Settling velocity, Stability, Leaching, BOD, Signature

R.D. Moccia

Guar gum in rainbow trout (*Oncorhynchus mykiss*) feed: The influence of quality and dose on stabilisation of faecal solids

Alexander Brinker *

A. Brinker / Aquaculture 267 (2007) 315–327 319

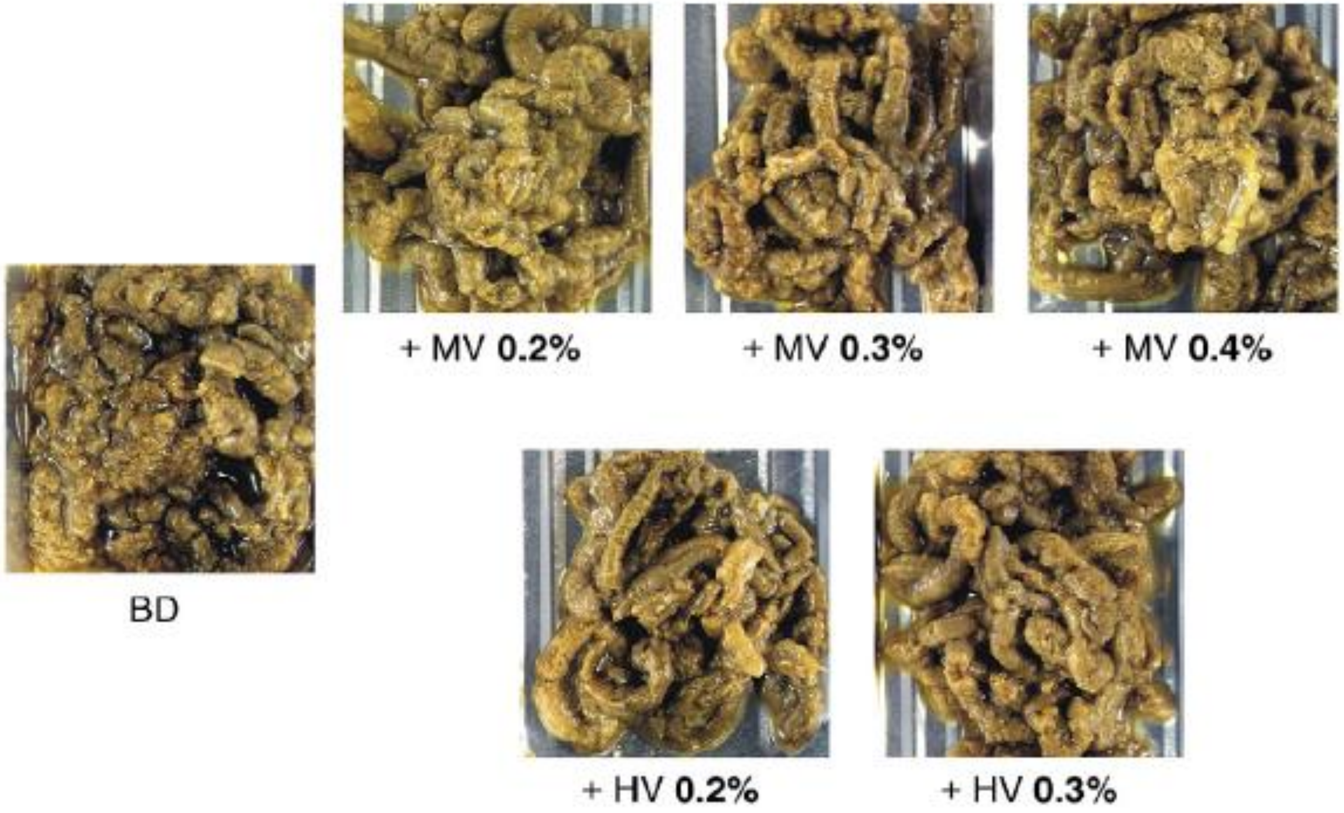


Fig. 1. Faeces from rainbow trout fed a basic diet (BD) and from trout fed the same diet but with the inclusion of various concentrations of two types of guar gum as binders (MV = mid-viscosity guar gum, HV = high-viscosity guar gum). Faeces were obtained by intestinal dissection. Note that the faeces containing binder are more structured and less pulpy than those resulting from the basic diet (BD).

Goal:

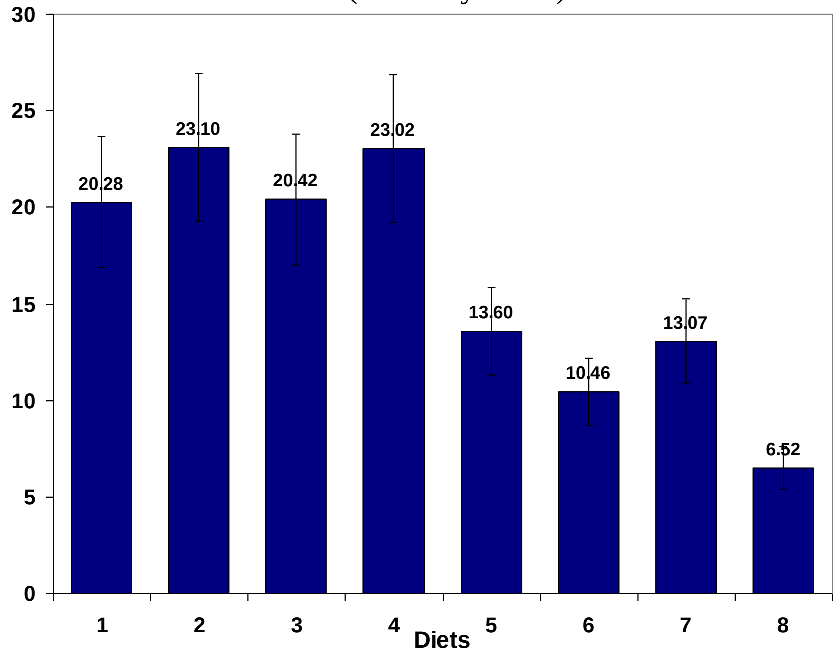
Making the fecal material more cohesive and easier to recover by settling and filtration

Source: Ogunkoya, A.E., G.I. Page, M. A. Adewolu, and D.P. Bureau. 2006. Dietary incorporation of soybean meal and exogenous enzyme cocktail can affect physical characteristics of faecal material egested by rainbow trout (*Oncorhynchus mykiss*). Aquaculture 254: 466-475.

Diet	Description
1	Diet with 0% soybean meal
2	Diet with 10% soybean meal
3	Diet with 20% soybean meal
4	Diet 1 suppl. with 1 g Superzyme CS/kg
5	Diet 2 suppl. with 1 g Superzyme CS/kg
6	Diet 3 suppl. with 1 g Superzyme CS/kg
7	Diet 2 suppl. with 2.5 g Superzyme CS/kg
8	Diet 3 suppl. with 2.5 g Superzyme CS/kg

Cohesiveness of fecal material

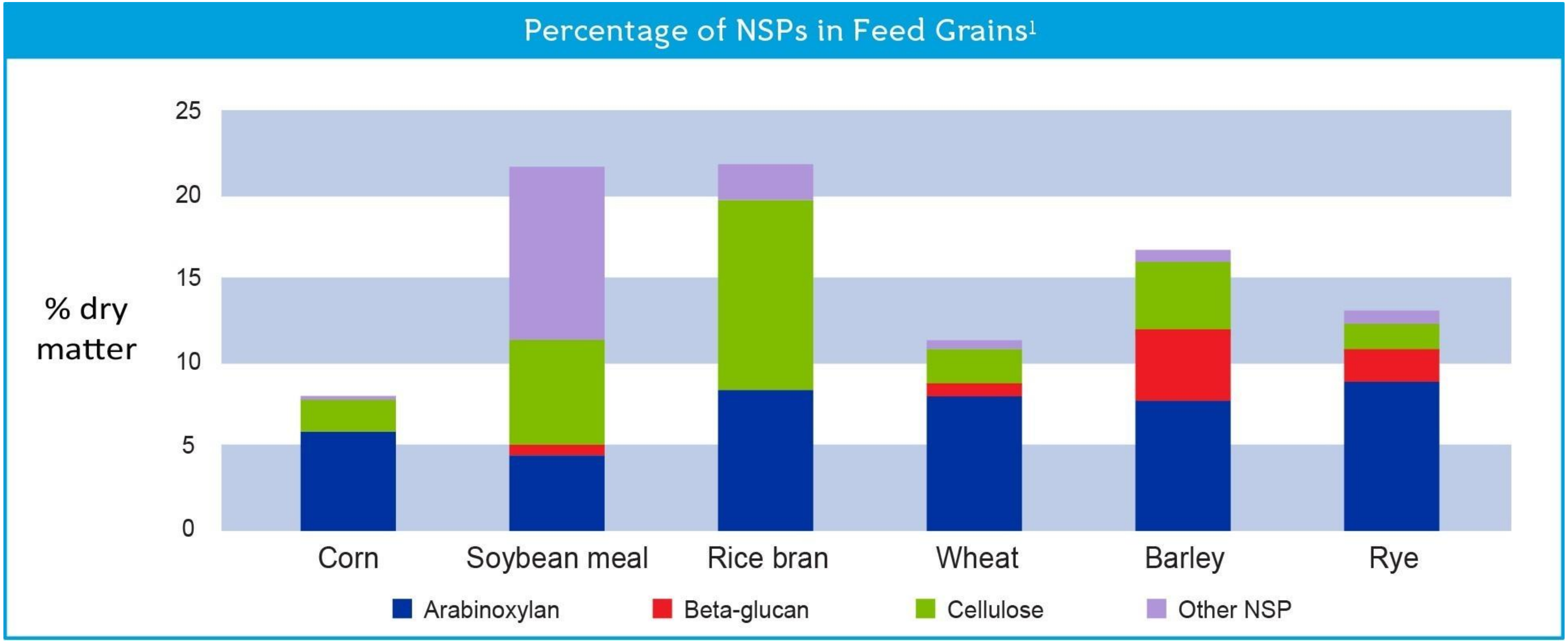
(Arbitrary index)

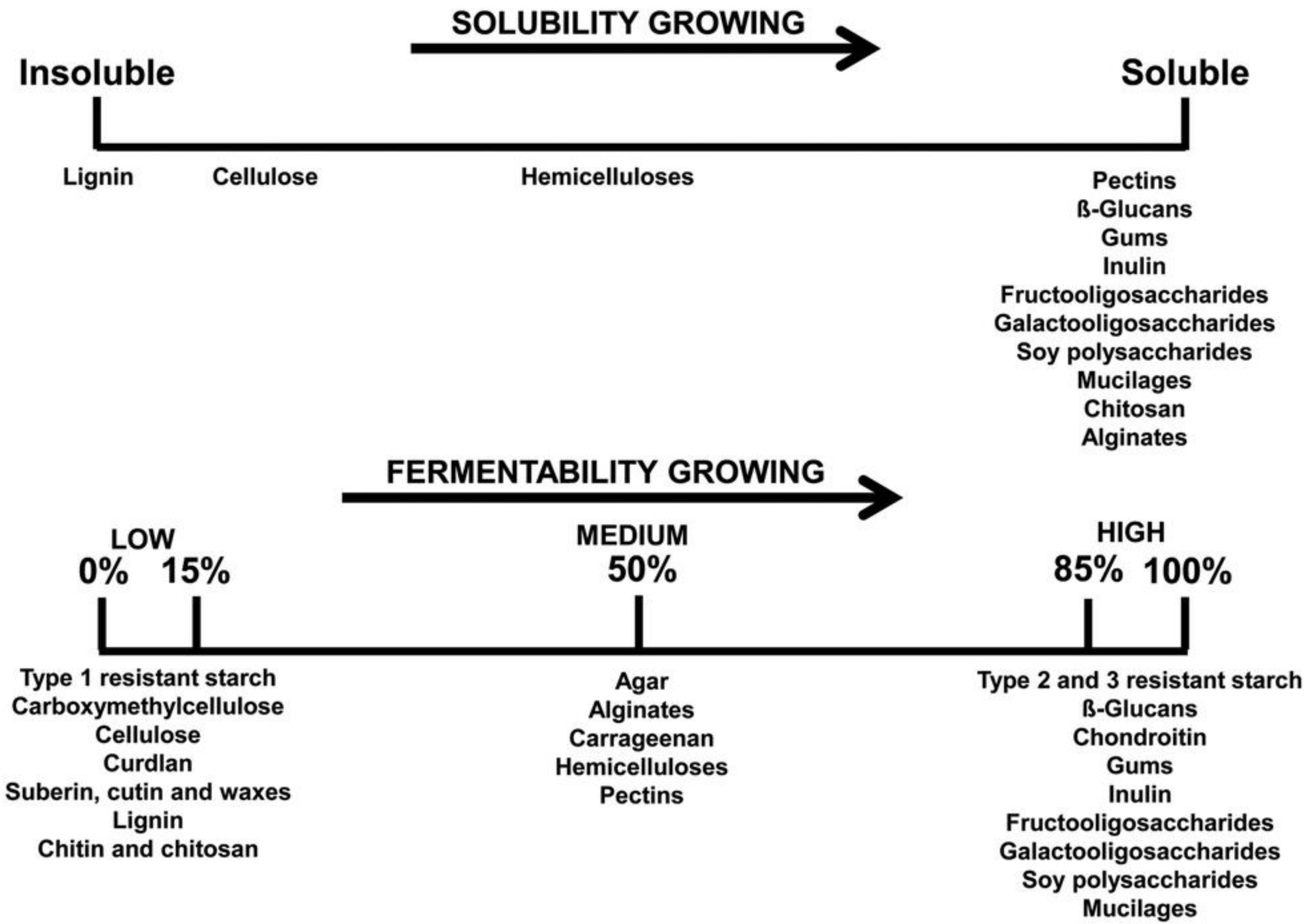


Diet composition and enzyme supplementation can affect physico-chemical characteristics of fecal material egested by fish

Goal:

Making the fecal material less cohesive and easier to breakdown and disperse


Percentage of NSPs in Feed Grains[1]
% dry matter
25
20
15
10
5
0
Corn
Soybean meal
Rice bran
Wheat
Barley
Rye
Arabinoxylan
Beta-glucan
Cellulose
Other NSP


SOLUBILITY GROWING
Insoluble
Soluble
Lignin
Cellulose
Hemicelluloses
Pectins
ß-Glucans
Gums
Inulin
Fructooligosaccharides
Galactooligosaccharides
Soy polysaccharides
Mucilages
Chitosan
Alginates
FERMENTABILITY GROWING
LOW
0%
15%
MEDIUM
50%
HIGH
85%
100%
Type 1 resistant starch
Carboxymethylcellulose
Cellulose
Curdlan
Suberin, cutin and waxes
Lignin
Chitin and chitosan
Agar
Alginates
Carrageenan
Hemicelluloses
Pectins
Type 2 and 3 resistant starch
ß-Glucans
Chondroitin
Gums
Inulin
Fructooligosaccharides
Galactooligosaccharides
Soy polysaccharides
Mucilages

Feed Composition and Incidence of Disease in Shrimp Culture

- Higher quality feeds (e.g. higher protein) anecdotally associated with better survival

- Are these feeds making the animal more resistant?

- Could the amount and types of solid wastes associated with different feeds play a role?
  - Lower quality / nutritional density feeds = more solid waste outputs
  - Higher quality / nutrient density feeds = less solid waste outputs

frontiers in Microbiology

ORIGINAL RESEARCH
published: 18 October 2018
doi: 10.3389/fmicb.2018.02457

Bacterial Abundance and Community Composition in Pond Water From Shrimp Aquaculture Systems With Different Stocking Densities

Yustian Rovi Alfiansah[1,2]*, Christiane Hassenrück[1], Andreas Kunzmann[1], Arief Taslihan[3], Jens Harder[4] and Astrid Gärdes[1]

[1] Leibniz Centre for Tropical Marine Research (ZMT), Bremen, Germany, [2] Laboratory of Marine Microbiology, Research Center for Oceanography, Indonesian Institute of Sciences, Jakarta, Indonesia, [3] Balai Besar Pengembangan Budidaya Air Payau, Jepara, Indonesia, [4] Department of Microbiology, Max Planck Institute for Marine Microbiology (MPI), Bremen, Germany

Vibrio, a potential opportunistic pathogen for L. vannamei has been found in higher proportions in the particulate fractions.

This might indicate that marine aggregates, can accumulate potentially pathogenic bacteria.

Vibrio can convert from non-virulent to virulent under certain cell density threshold or if dramatic environmental changes occur.

TABLE 2 | Total bacterial cell numbers in the free-living (FL) and the particle attached (PA) fractions.

Day	Fractions			
	FL [x 10^7 cells mL^{-1}]		PA [x 10^5 cells mL^{-1}]	
	S	T	S	T
10	0.06 ± 0.01^a	0.09 ± 0.02^a	0.62 ± 0.08^a	0.50 ± 0.05^a
40	1.83 ± 0.13^b	3.09 ± 2.34^b	6.77 ± 0.50^b	6.40 ± 0.24^b
50	2.94 ± 1.04^b	2.13 ± 0.11^b	6.51 ± 0.79^b	6.55 ± 0.31^b
60	3.79 ± 0.89^c	5.01 ± 0.85^c	6.16 ± 0.67^b	6.09 ± 0.37^b
70	3.47 ± 0.94^{bc}	3.64 ± 1.22^{bc}	7.68 ± 0.36^c	7.42 ± 0.21^c

S = Semi-intensive 40 PL/M^2
T = Intensive 90 PL/M^2

Should maintain low suspended particulate matter and aggregate abundance and to avoid massive Vibrio growth.

SCIENTIFIC REPORTS

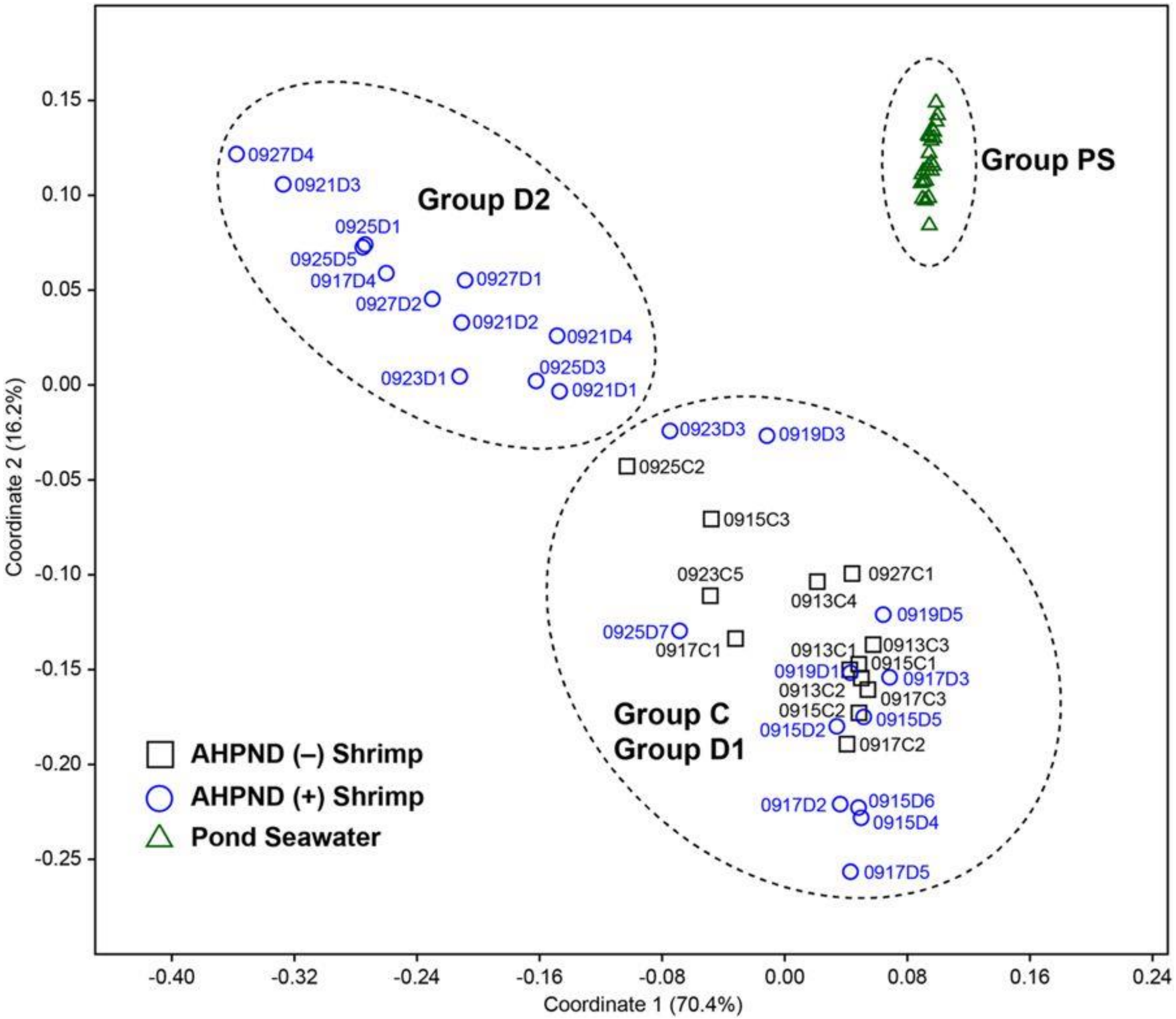
OPEN

Microbiome Dynamics in a Shrimp Grow-out Pond with Possible Outbreak of Acute Hepatopancreatic Necrosis Disease

Received: 5 May 2017
Accepted: 1 August 2017
Published online: 24 August 2017

Wei-Yu Chen[1], Tze Hann Ng[2], Jer-Horng Wu[1], Jiung-Wen Chen[1] & Han-Ching Wang[2,3]

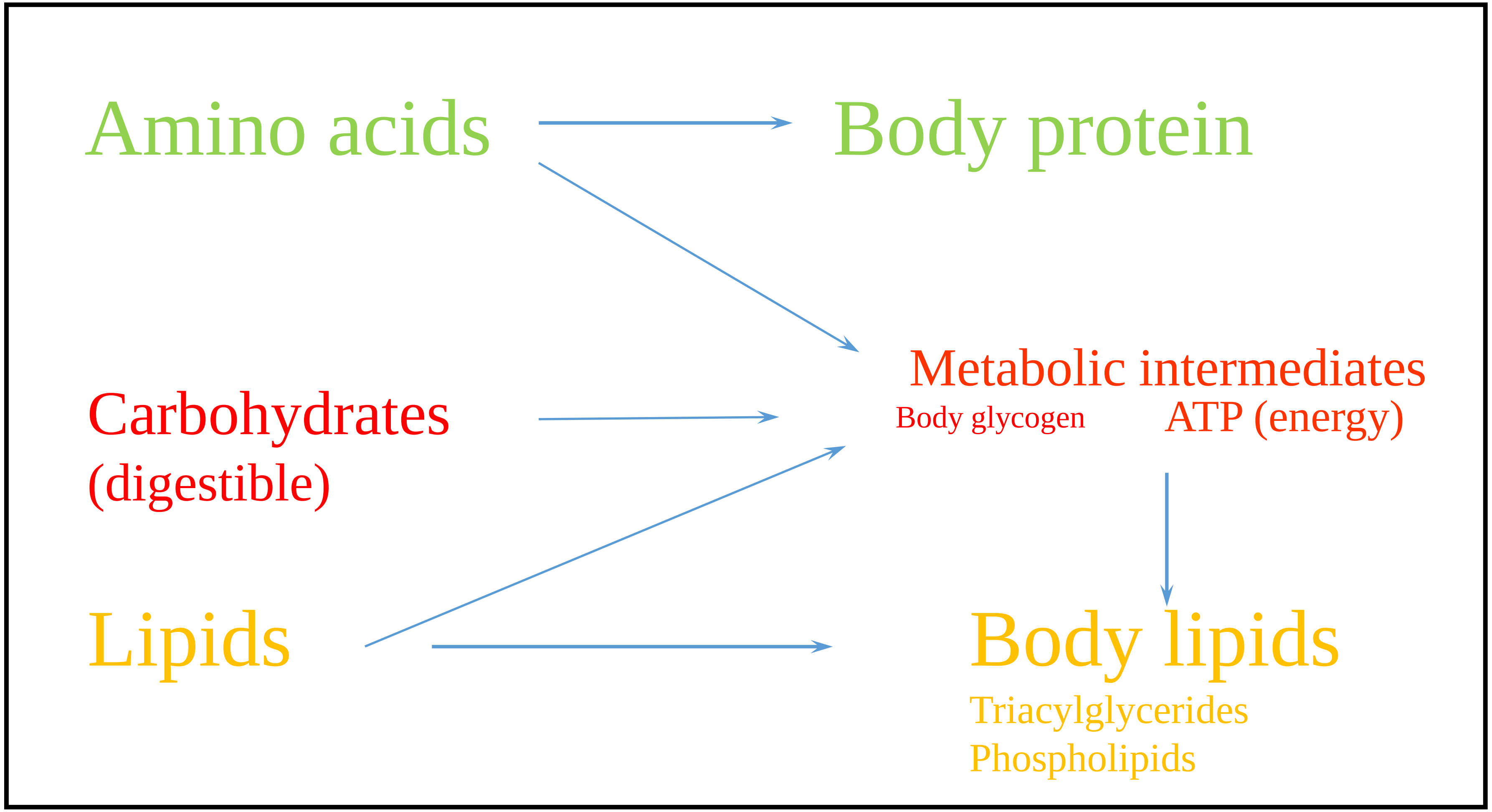
Principal co-ordinates analysis of bacterial community structures of the samples collected from the pond seawater (Group PS), healthy shrimp stomach (Group C), and shrimp stomach affected by AHPND (Groups D1 and D2).



Nitrogenous Wastes

Dissolved N wastes

- Impacted by efficiency of N retention of the animal
- Digestible protein to digestible energy ratio
- Amino acid composition of the digestible protein
- Species, life stage or body weight
- Stressors, disease, management practice



Amino acids
Body protein
Metabolic intermediates
Body glycogen
ATP (energy)
Carbohydrates
(digestible)
Lipids
Body lipids
Triacylglycerides
Phospholipids

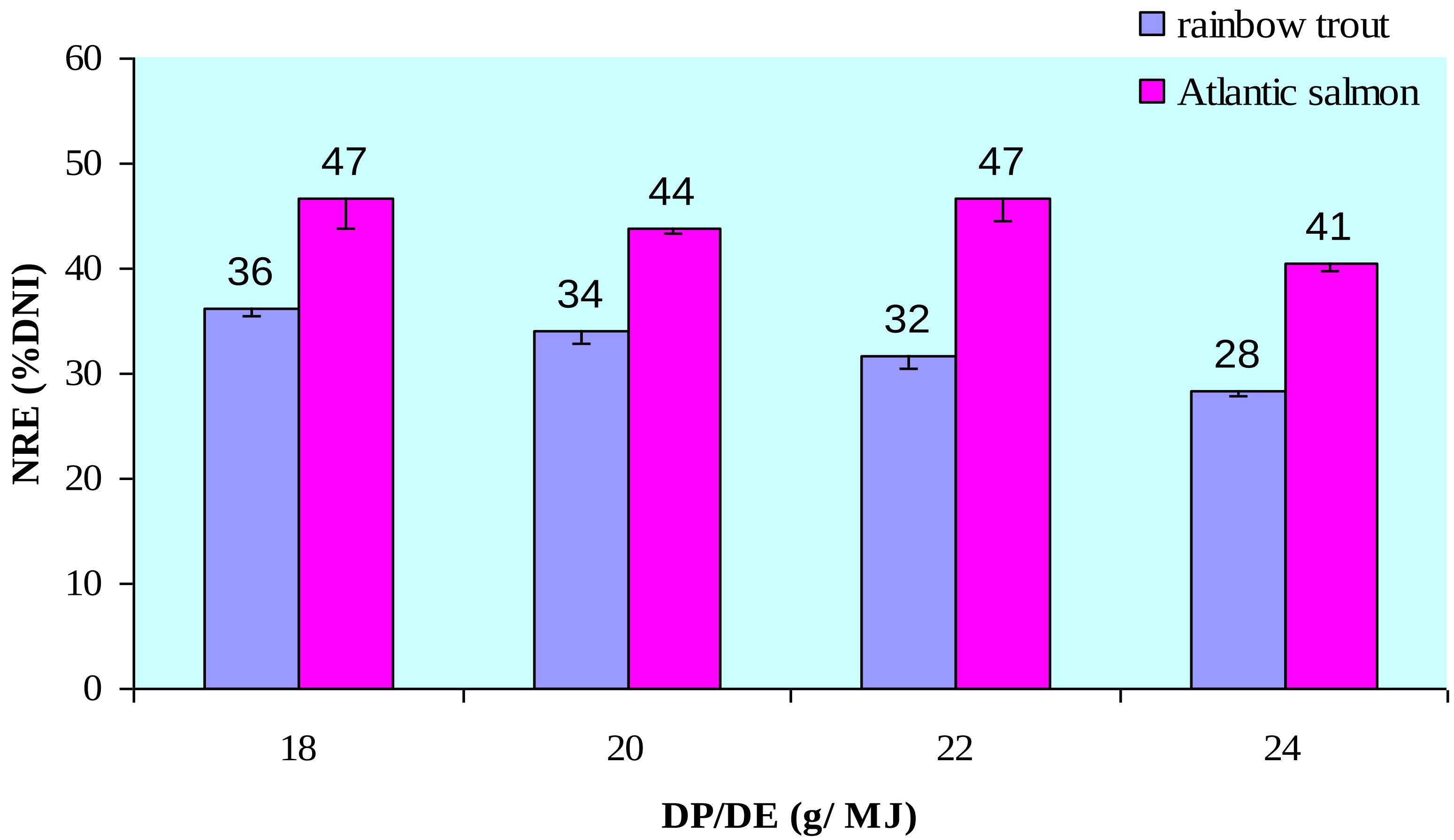
Optimizing Digestible Protein to Digestible Energy Ratio

	Diet			
	1	2	3	4
Diet formulation (g/100g feed)				
Fish meal, herring, 68% CP	34	29	25	22
Corn gluten meal, 60% CP	34	29	25	22
Blood meal, spray-dried	10	10	10	10
Wheat middlings, 17% CP		6.1	9.2	11
Whey, 10% CP	4.8	5.5	7.5	8.9
$CaHPO_4$			0.3	0.5
Lysine.HCl	0.2	0.4	0.5	0.6
Vitamins + minerals	3	3	3	3
Fish oil, herring	14	17	19.5	22
Calculated DP, DE and DP/DE				
DP (%)	49	45	41	37
Lipid (%)	19	21	23	26
DE (MJ, kg)	20	20	20	20
DP/DE (g, MJ)	24	22	20	18

Performance of Atlantic salmon (IBW = 460g) fed the four experimental diets for 44 weeks at 8.5°C.

Diet	Gain (g/fish)	TGC[1]	Feed intake (g/fish)	FE (gain:feed)
DP/DE = 24	**1200**	**0.161**	**1238**	**0.97**
DP/DE = 22	**1272**	**0.169**	**1325**	**0.96**
DP/DE = 20	**1214**	**0.163**	**1298**	**0.93**
DP/DE = 18	**1250**	**0.168**	**1310**	**0.95**
Significance[2]				
Linear	**N.S.**	**N.S.**	**N.S.**	**N.S.**
Quadratic	**N.S.**	**N.S.**	**N.S.**	**N.S.**

[1]Thermal-unit growth coefficient (TGC) = 100 $(FBW^{1/3} - IBW^{1/3}) / \Sigma$ (°C x days); IBW = initial body weight (g/fish) [2]Significance of linear or quadratic regression models using DP: DE as the independent variable.



Azevedo et al. (2004)

Optimal Dietary Protein to Digestible Energy Ratio for Pacu

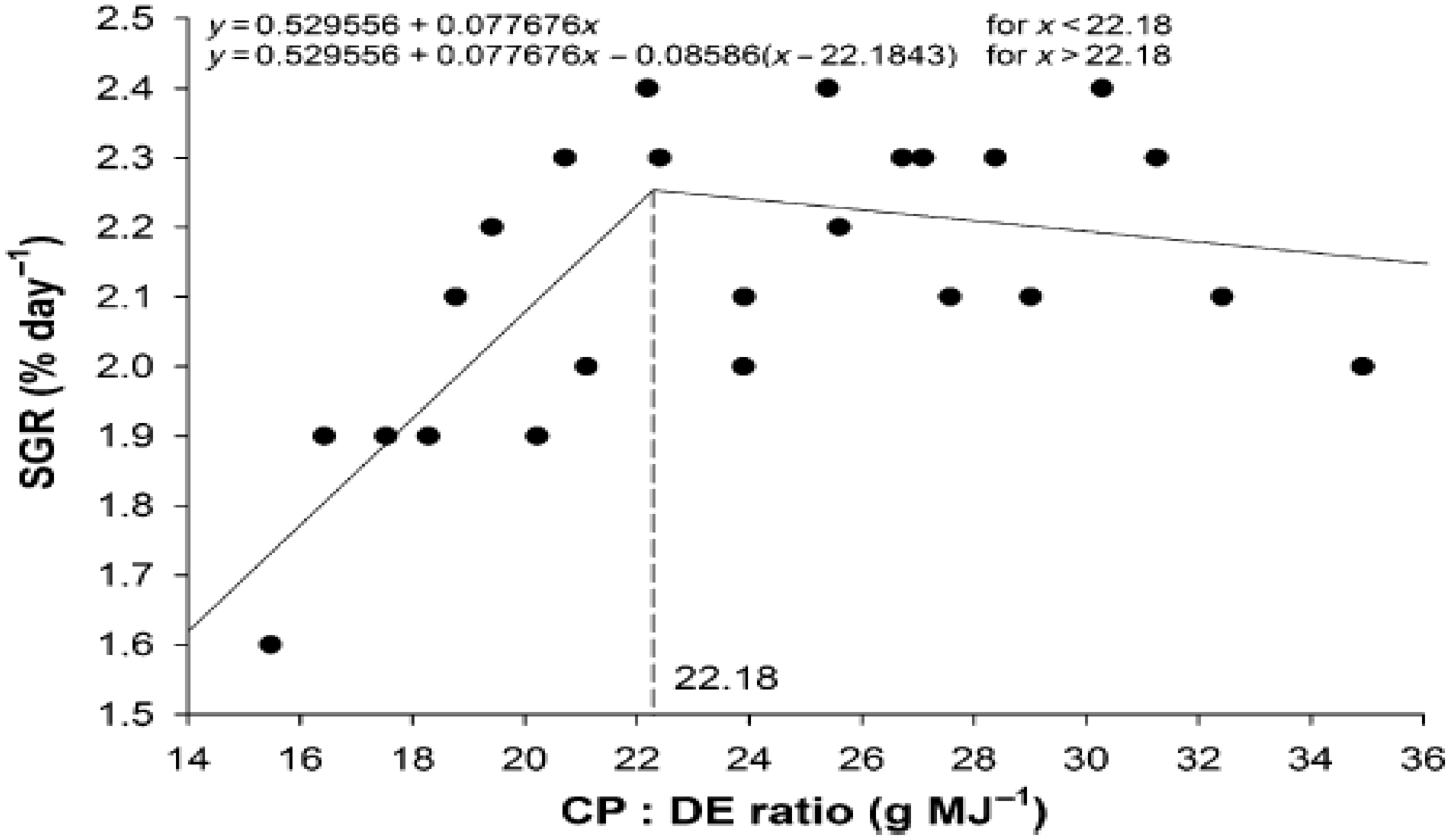
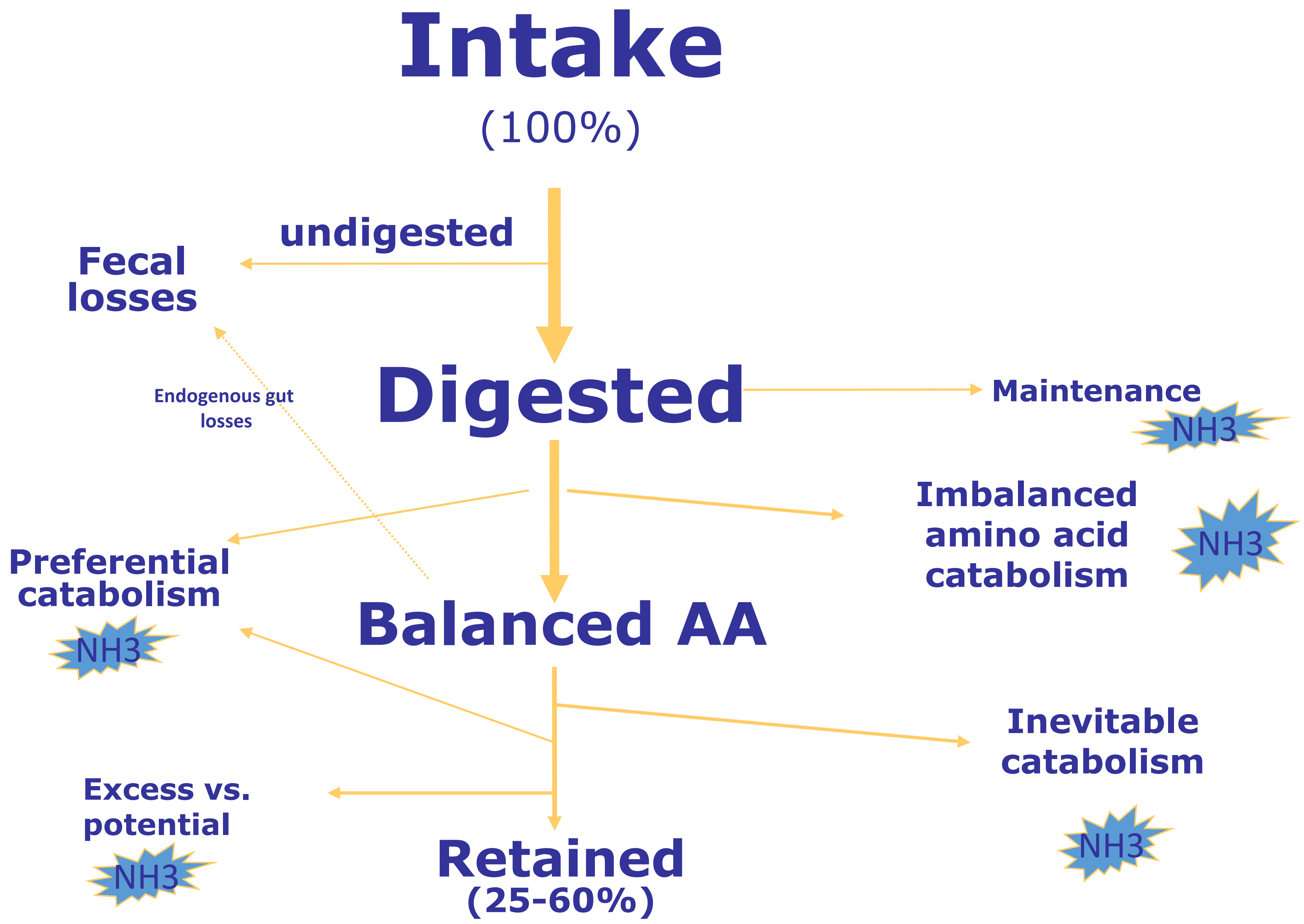
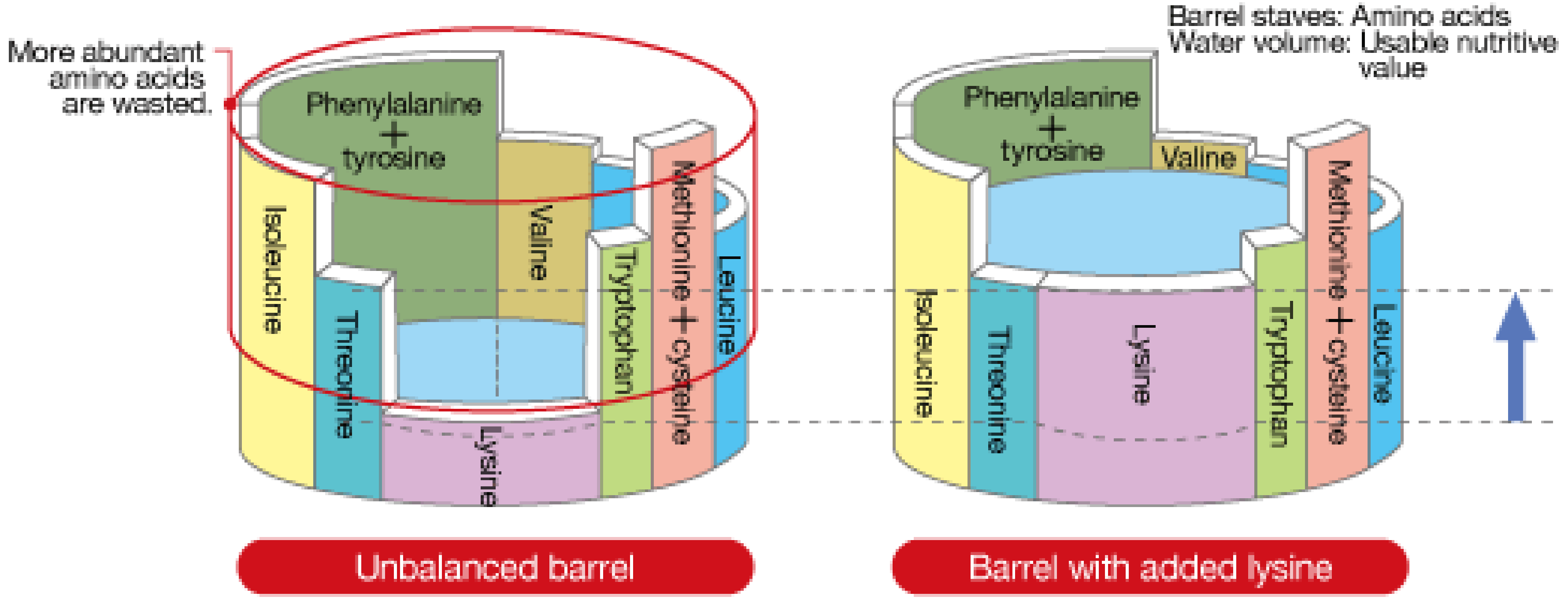


Figure 2 Optimal crude protein : digestible energy ratio (CP : DE) of juvenile pacu (*Piaractus mesopotamicus*) by two-slope broken line model as a function of specific growth rate (SGR).

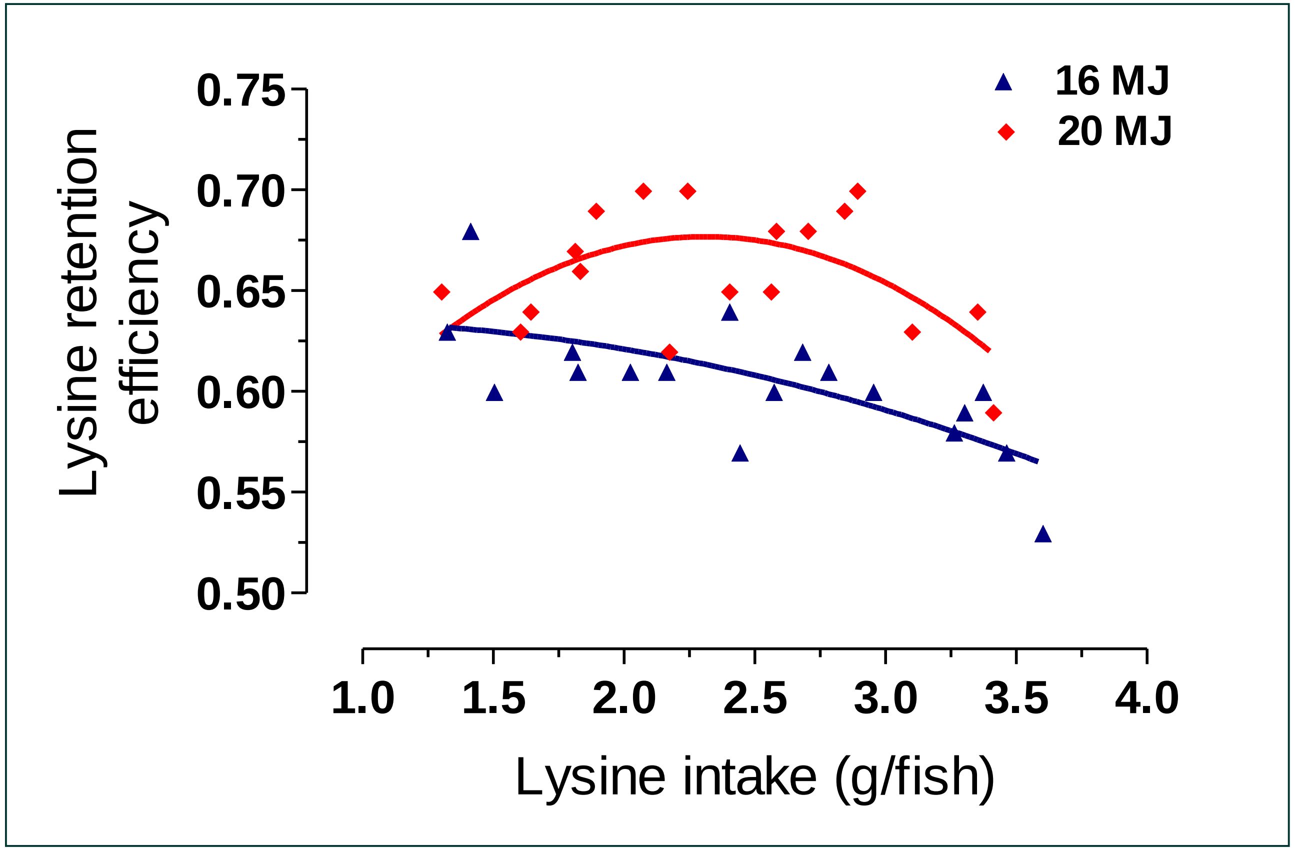
Bicudo et al. (2009)

Factorial Amino Acid Utilization Scheme




More abundant amino acids are wasted.
Phenylalanine + tyrosine
Valine
Isoleucine
Threonine
Lysine
Tryptophan
Methionine + cysteine
Leucine
Barrel staves: Amino acids
Water volume: Usable nutritive value
Unbalanced barrel
Barrel with added lysine

Efficiency of lysine utilization in response to the lysine intake



- ✓ Higher efficiency of lysine utilization at higher dietary DE levels.

Encarnaçaõ et al. (2004)

Oxygen and Carbon Dioxide

Indirect Calorimetry

Combustion:

Organic compounds + O_2 = CO_2 + H_20 + Heat

(Wood, gas, paper)

Respiration:

Organic compounds + O_2 = CO_2 + H_20 + ATP + Heat

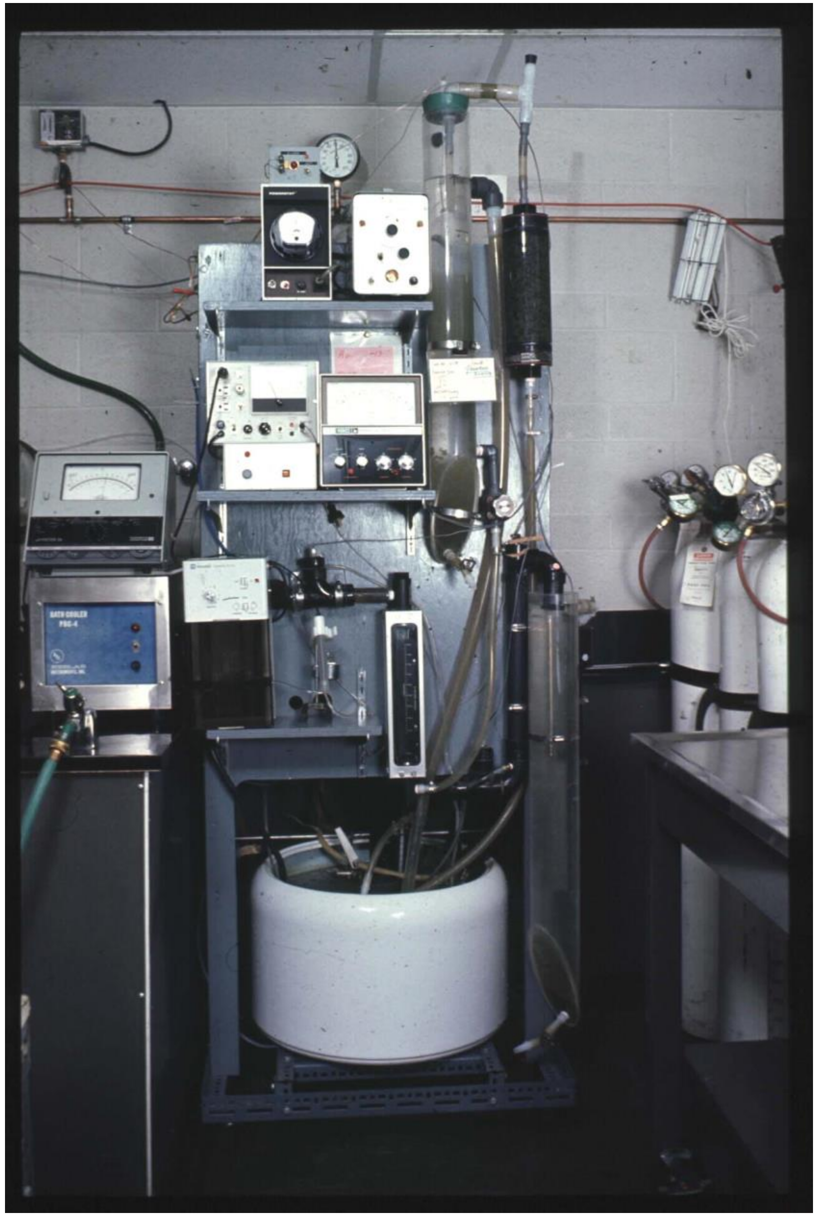
(AA, fatty acids, glucose)

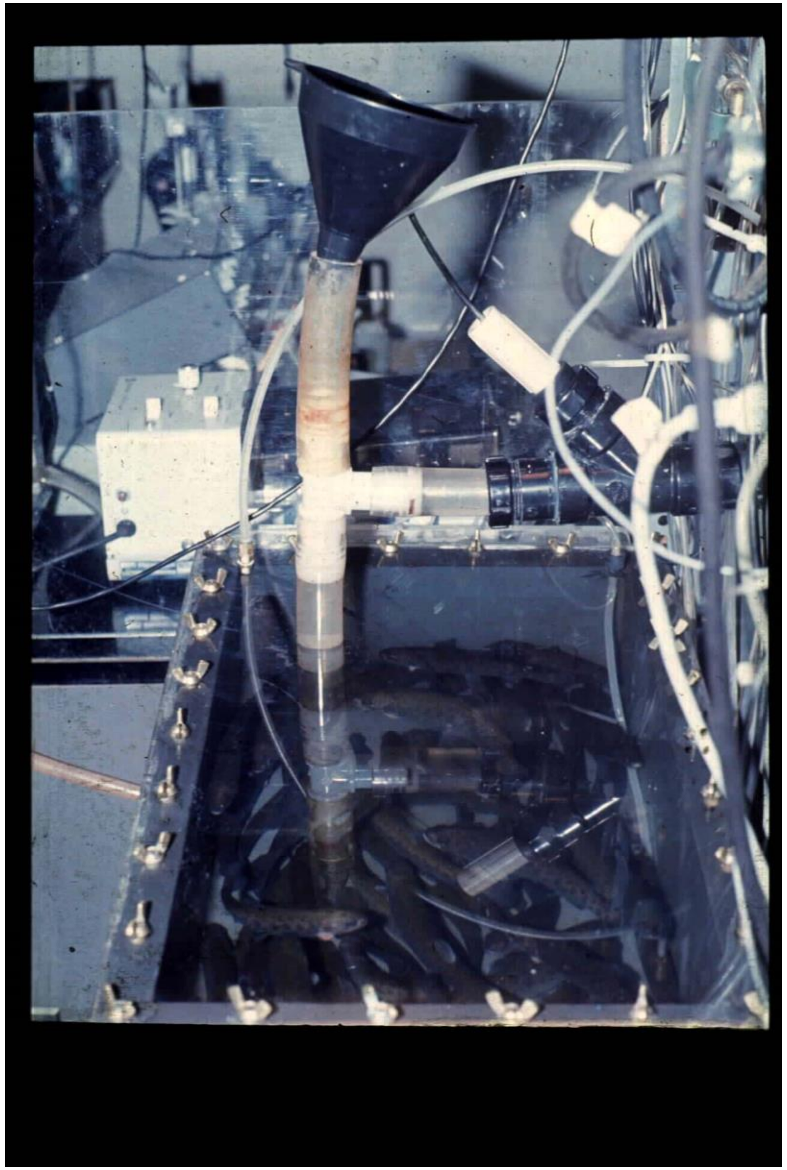
ATP = ADP + Pi + Heat

therefore

Organic compounds + O_2 = CO_2 + H_20 + Heat

Fish Respirometry





Predicting Heat Losses from Oxygen Consumption (or vice a versa)

Oxycalorific coefficient (Q_{Ox}):

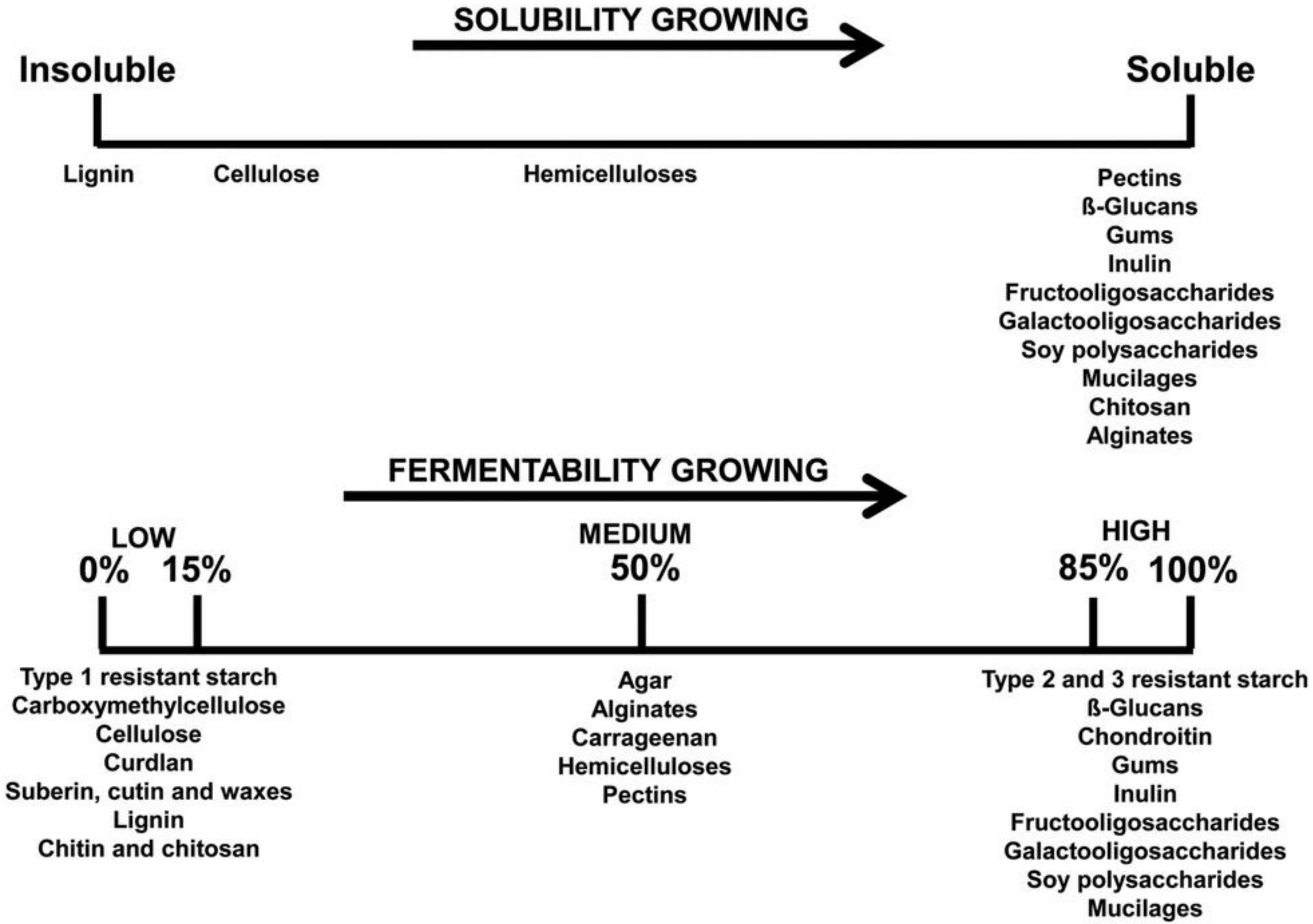
Coefficient used to estimate heat production from oxygen consumption

Q_{Ox}:	**Lipids (mean value) =**	**13.72 J/ mg O_2**
	Glucose =	**14.76 J/ mg O_2**
	Amino acids (to NH_3) =	**13.36 J/ mg O_2**
Q_{Ox}	**mixed nutrients (fish feed) =**	**13.6 J/mg O_2** or k**J/g O_2**

Substance	**Respiratory Quotient O_2/CO_2**
Carbohydrates	1.0
Protein/Amino acids	0.8 – 0.9
Fat	0.7
Mixed Nutrients:	0.8

Energy and oxygen requirements and expected feed efficiency of Asian sea bass (*Lates calcarifer*)

Live weight	Growth rate[c]	RE[d]	H_eE[e]	H_iE + (UE + ZE)[f]	DE[g]	Oxygen[h]	Feed efficiency[i]
g/fish	g/fish per d	Mcal/kg (MJ/kg) weight gain				g/kg weight gain	
10	1.1	1.08 (4.5)	0.29 (1.2)	0.74 (3.1)	2.13 (8.9)	319	2.6
50	2.2	1.36 (5.7)	0.55 (2.3)	0.93 (3.9)	2.84 (11.9)	454	1.9
100	3.0	1.51 (6.3)	0.69 (2.9)	1.03 (4.3)	3.25 (13.6)	533	1.7
250	4.4	1.72 (7.2)	0.98 (4.1)	1.17 (4.9)	3.90 (16.3)	666	1.4
500	5.9	1.91 (8.0)	1.29 (5.4)	1.29 (5.4)	4.49 (18.8)	794	1.2
1000	8.0	2.10 (8.8)	1.67 (7.0)	1.43 (6.0)	5.21 (21.8)	953	1.0
2000	10.7	2.32 (9.7)	2.15 (9.0)	1.58 (6.6)	6.07 (25.4)	1152	0.9
3000	12.7	2.46 (10.3)	2.51 (10.5)	1.67 (7.0)	6.64 (27.8)	1290	0.8


SOLUBILITY GROWING
Insoluble
Soluble
Lignin
Cellulose
Hemicelluloses
Pectins
ß-Glucans
Gums
Inulin
Fructooligosaccharides
Galactooligosaccharides
Soy polysaccharides
Mucilages
Chitosan
Alginates
FERMENTABILITY GROWING
LOW
0%
15%
MEDIUM
50%
HIGH
85%
100%
Type 1 resistant starch
Carboxymethylcellulose
Cellulose
Curdlan
Suberin, cutin and waxes
Lignin
Chitin and chitosan
Agar
Alginates
Carrageenan
Hemicelluloses
Pectins
Type 2 and 3 resistant starch
ß-Glucans
Chondroitin
Gums
Inulin
Fructooligosaccharides
Galactooligosaccharides
Soy polysaccharides
Mucilages

Natural Food Composition

- Natural food is highly variable in composition
- Highly condition-specific
- Can be stimulated with inputs (inorganic fertilizers, fermentable CHO)
- Can be a source of protein, EAA, lipids, EFA, vitamins, cholesterol, carotenoid pigments, etc.

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Impacts of Grazing by Milkfish (Chanos chanos Forsskal) on Periphyton Growth and its Nutritional Quality in Inland Saline Ground Water : Fish Growth and Pond Ecology

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Composition of Periphyton

Treatment	Salinity	Dry Matter	Protein	Fat	Ash
	ppt	%	%	%	%
Grazed condition	10	28.7	19.4	1.9	35.3
	15	30.0	20.7	1.9	38.2
	20	28.0	18.5	1.8	34.1
Ungrazed condition	10	23.7	35.7	3.8	29.5
	15	24.3	37.9	4.2	30.4
	20	22.6	33.2	3.2	28.6

The effect of carbohydrate addition on water quality and the nitrogen budget in extensive shrimp culture systems

B. Hari [a,1], B. Madhusoodana Kurup [a], Johny T. Varghese [a],
J.W. Schrama [b], M.C.J Verdegem [b,*]

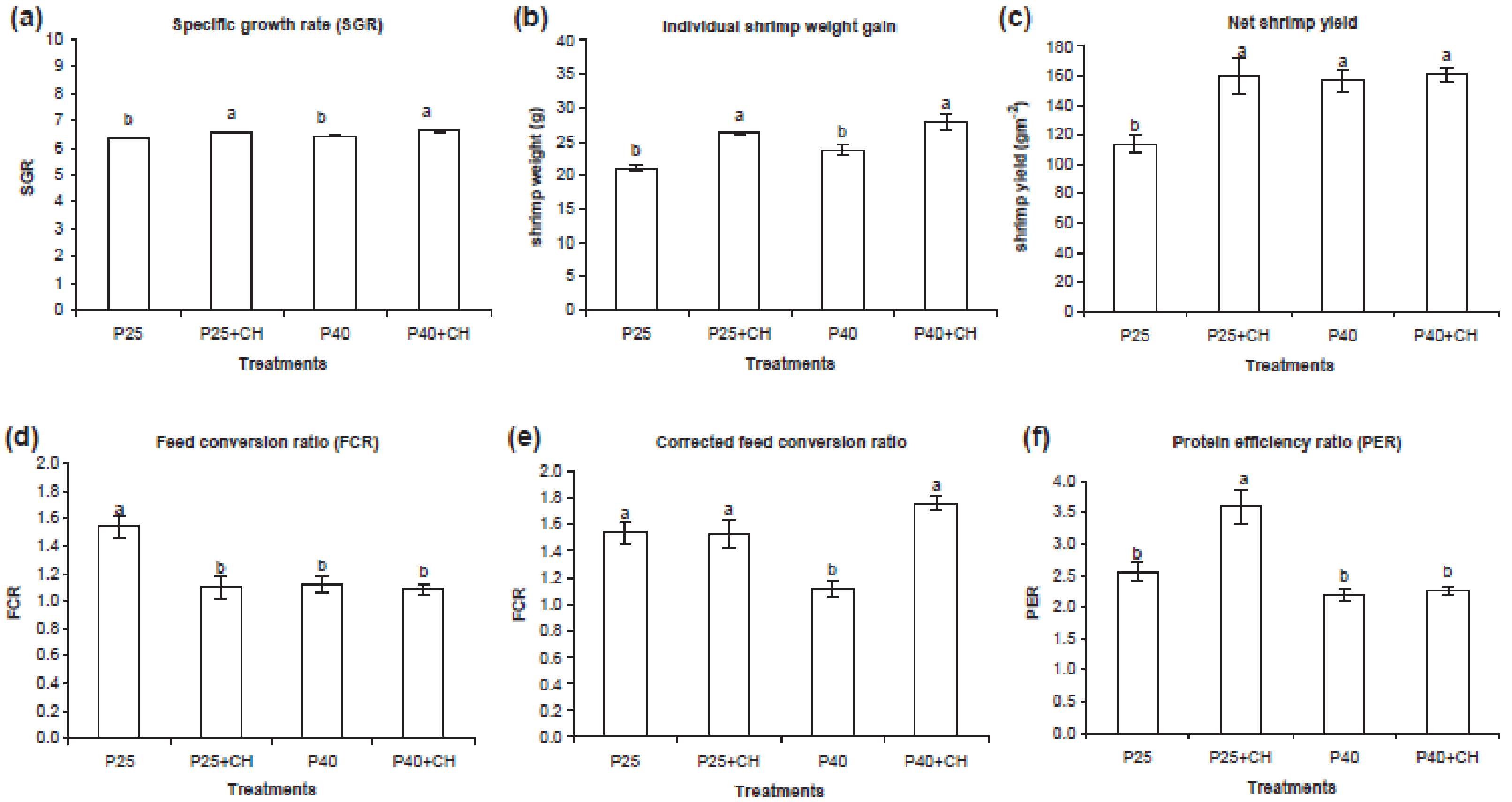


Fig. 4. Effect of carbohydrate addition and protein levels on weight, net shrimp yield, SGR, FCR and PER of *Penaeus monodon* reared in outdoor tanks Mean values were presented with SE as error bars; means with different script differ significantly ($P<0.05$) P25: 25% dietary protein; P25+CH: 25% dietary protein+carbohydrate addition; P40: 40% dietary protein; P40+CH: 40% dietary protein+carbohydrate addition.

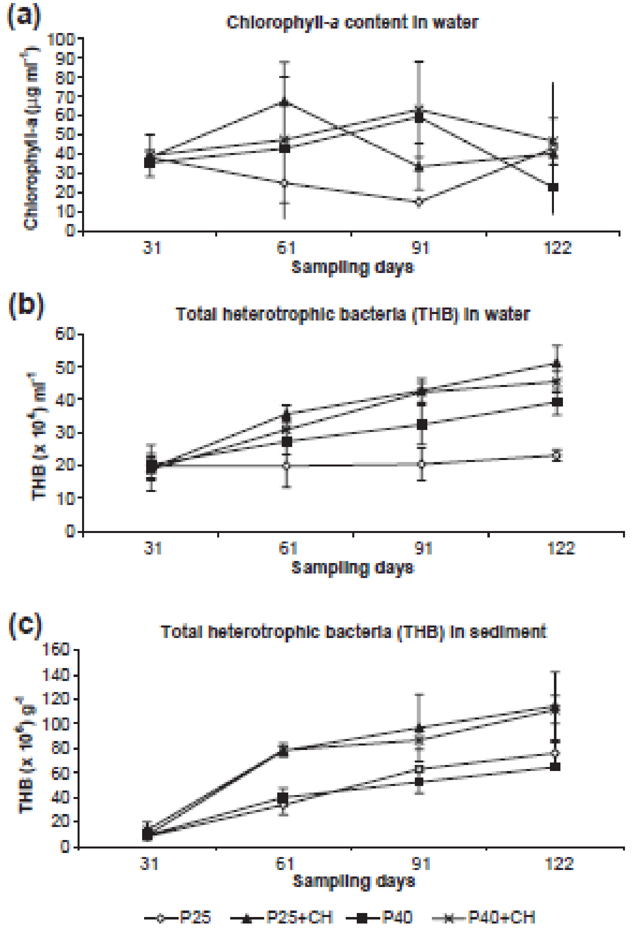


Fig. 2. Effect of carbohydrate addition and protein levels on the chlorophyll-*a* content in water and total heterotrophic bacteria (THB) (Mean ± S.E.) of the outdoor tanks stocked with *Penaeus monodon* P25: 25% dietary protein; P25+CH: 25% dietary protein+carbohydrate addition; P40: 40% dietary protein; P40+CH: 40% dietary protein+carbohydrate addition.

Cholesterol

Table 1. Proximate composition, fatty acid profile, and sterol profile of dried *Schizochytrium* sp produced by fermentation[1]

Proximate composition[1], % weight	
Moisture	4.9±0.7
Protein	25.3±3.8
Crude Fiber	3.6±0.7
Ash	13.0±2.0
Crude Fat	48.3±4.5
Carbohydrate	4.9±2.8
Fatty acid composition[2], % total fatty acids	
C14:0 myristate	13.1
C16:0 palmitate	29.4
C16:1 palmitoleate	11.7
C18:0 stearate	1.1
C18:1 vaccenate	1.1
C18:2(ω6) linoleate	1.9
C18:3(ω3) linolenate	2.7
C20:3(ω6) homogammalinolenate	0.8
C20:5(ω3) eicosapentaenoate	0.8
C22:5(ω6) docosapentaenoate	12.0
C22:6(ω3) docosahexaenoate	25.3
Sterol content[2], mg/g	
Cholesterol	3.9
Brassicasterol	1.7
Stigmasterol	1.4
Other sterols	2.6
Nucleic acid content, % dry weight	0.5

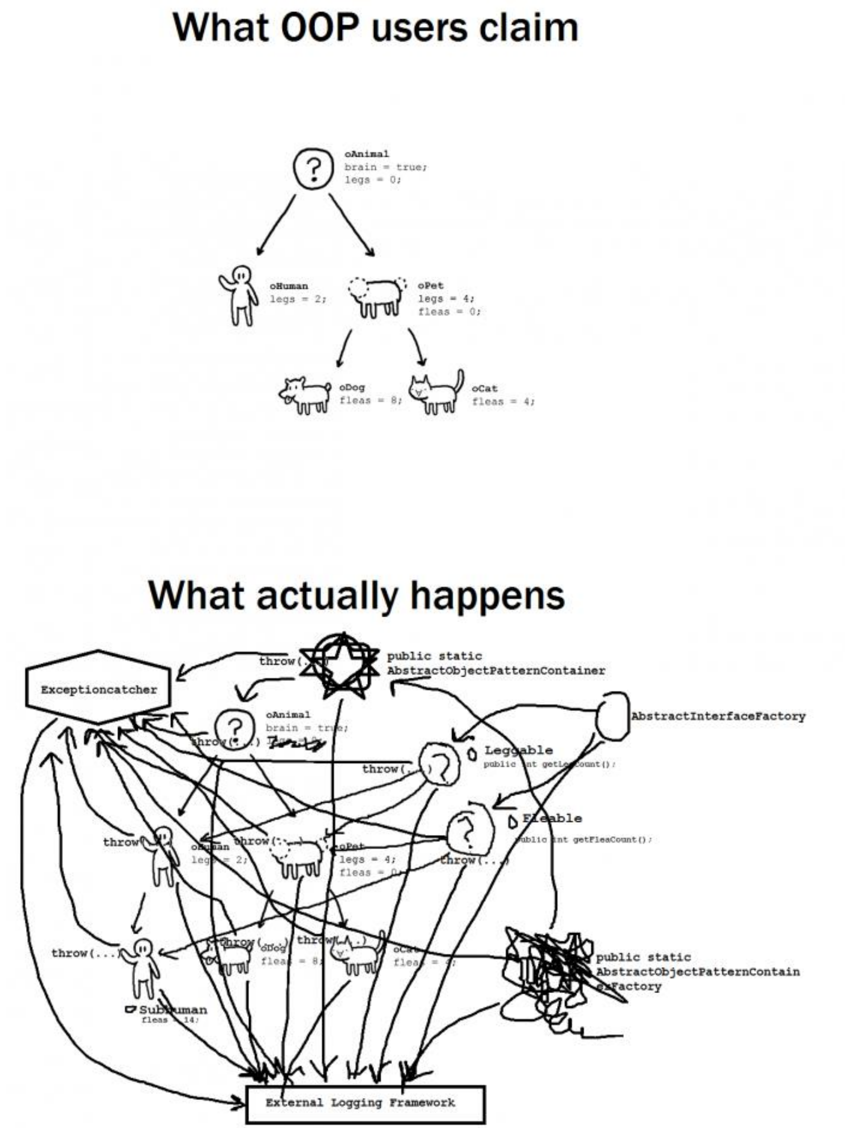
Table 1 Cholesterol content of marine algae of the Caribbean

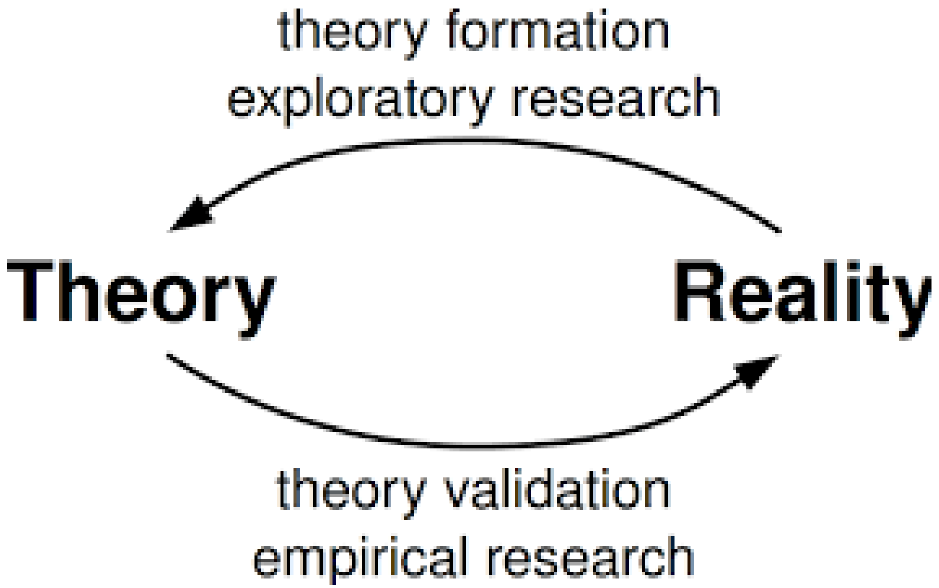
Order	Family	Genus and Species	Cholesterol (μg/mg of crude extract)
Red			
Ceramiales	Rhodomelaceae	*Acanthophora spicifera*	0.657
		Laurencia papillosa	1.219
Nemaliales	Chaetangiaceae	*Galaxaura oblongata*	0.396
	Helminthocladiaceae	*Liagora* species	0.425
Gigartinales	Gracilariaceae	*Gracilaria foliifera*	0.677
Green			
Caulerpales	Bryopsidaceae	*Bryopsis plumosa*	0.069
	Caulerpaceae	*Caulerpa racemosa*	0.648
		C sertularioides	0.389
Ulvales	Ulvaceae	*Ulva lactuca*	0.260
Brown			
Dictyotales	Dictyotaceae	*Lobophora variegata*	0.581
Fucales	Sargassaceae	*Sargassum polyceratium*	0.547

Composition of High DHA *Schizochytrium* Algae Biomass

Nutritional Specifications and Intensity of Production

Parameters	Semi-Intensive/Bioflock	Intensive	Super-Intensive/RAS
Dry matter digestibility	Condition-specific	Higher = Better	Higher = Better
Digestible Protein	Flexible	Higher = Better	Higher = Better
Digestible Protein: Digestible Energy	Flexible	Flexible	Optimize
Protein Quality	Flexible	Important	Very important
Essential Fatty Acids and Cholesterol	Condition-specific	Important	Very important
Vitamins and Micronutrients	Flexible	Important	Very important


What OOP users claim
oAnimal
brain = true;
legs = 0;
oHuman
legs = 2;
oPet
legs = 4;
fleas = 0;
oDog
fleas = 8;
oCat
fleas = 4;
What actually happens
Exceptioncatcher
public static
AbstractObjectPatternContainer
AbstractInterfaceFactory
Leggable
Fleable
public static
External Logging Framework


theory formation
exploratory research
Theory
Reality
theory validation
empirical research