Alternative Approaches for Removing Fish Meal and Oils from Farmed Shrimp Diets Using Plant and Poultry Meals with Marine Algal Products

Craig L. Browdy

DNR

Marine Resources Research Institute
Waddell Mariculture Center
Charleston, SC USA
browdyc@dnr.sc.gov

SCDNR: Craig L. Browdy, John W. Leffler

Diet formulation and testing: D. Allen Davis – Auburn University, Tzachi M. Samocha – Texas Agricultural Experiment Station, Robert A. Bullis – Advanced Bionutrition Corporation

Diets manufactured by: Zeigler Bros. Inc. Gardners PA

Lipid Analysis: Gloria Seaborn – NOAA's Center for Coastal Environmental Health and Biomolecular Research

Funded through:

USDA - Cooperative State Research, Education and Extension Service
US Marine Shrimp Farming Program

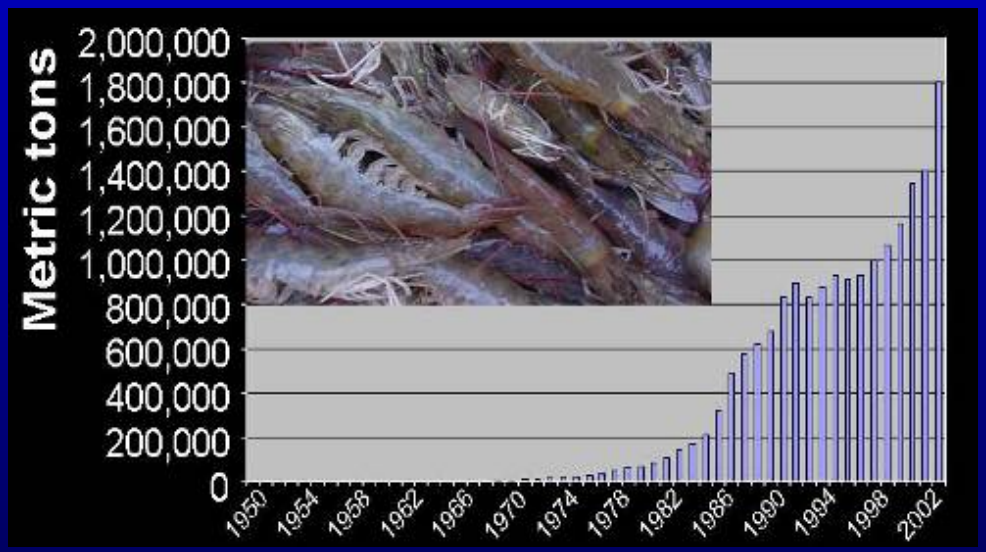
Advanced Bionutrition Corporation
NOAA Small Business Innovation Research

NOAA
Oceans and Human Health

USDA - Cooperative State Research , Education and Extension Service
Integrated Organic Program

Feed production and fish meal use

- **World feed production 630 million tons** (Global Information Inc.)
- **Aquaculture 4%**
  Uses 57% world fish meal
- **Shrimp Culture**
  - **4% volume**
  - **20% value**
  - **Uses 23% fish meal used by aquaculture**



Tacon, A.G.J., M. R. Hasan, R. P. Subasinghe 2006. Use of fishery resources as feed inputs to aquaculture development: Trends and policy implications. FA Fisheries Circular No 1018. P 114.

Feed production and fish meal use

- **World feed production 630 million tons**
  (Global Information Inc.)
- **Aquaculture 4%**
  Uses 57% world fish meal
- **Shrimp Culture**
  - **4% volume**
  - **20% value**
  - **Uses 23% fish meal used by aquaculture**

Simple Facts:
1) Supply is limited
2) Use is increasing
3) Prices are going up
4) Toxin levels a concern

Tacon, A.G.J., M. R. Hasan, R. P. Subasinghe 2006. Use of fishery resources as feed inputs to aquaculture development: Trends and policy implications. FA Fisheries Circular No 1018. P 114.

Fish meal and fish oil free diets
Organically certifiable diets

- Environmentally Friendly
  - Reduce pressure on pelagic fisheries
- Contaminant Free
  - Mercury, organochlorine compounds etc.
- Feed costs and potential for specialty markets
- Attention to PUFA especially DHA and EPA
  - Lower heart disease and stroke risk
  - Brain development and health

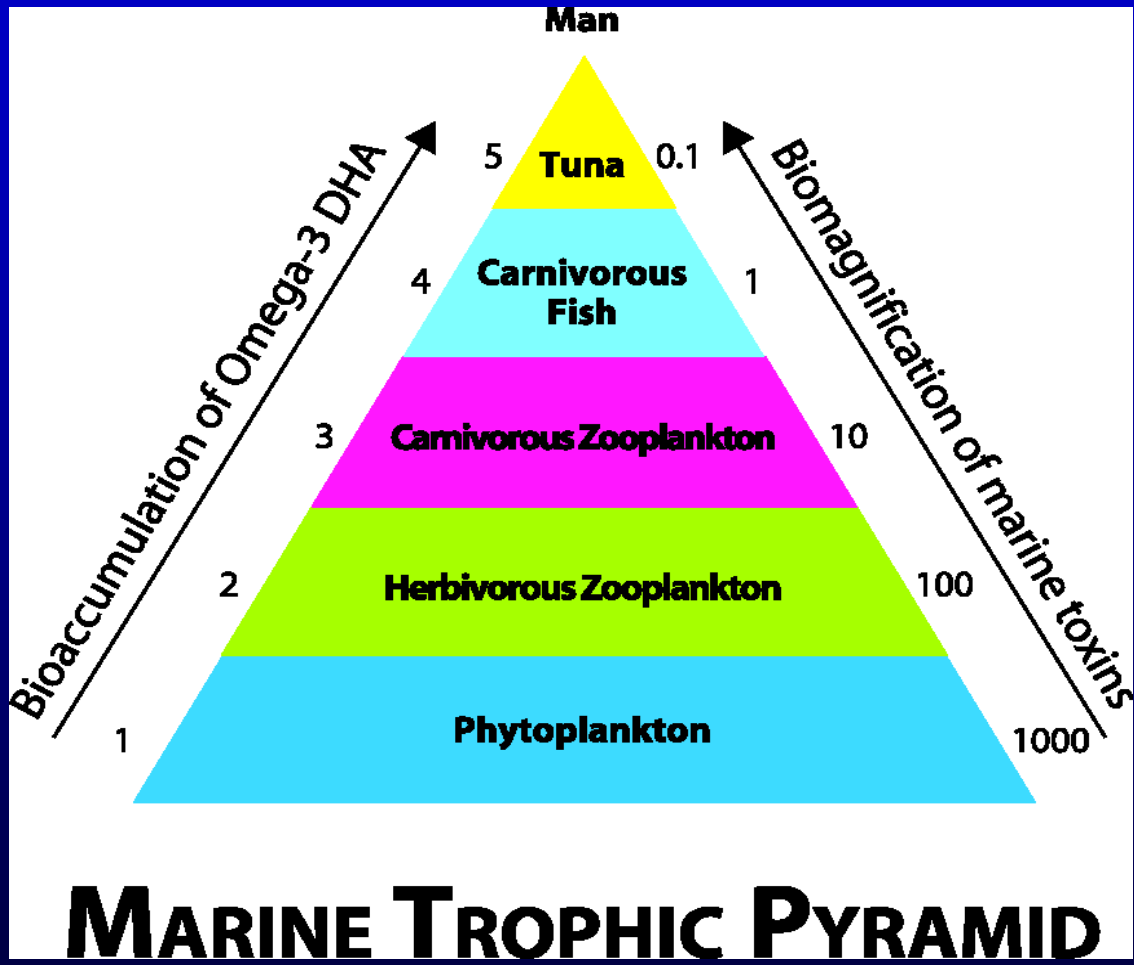
DHA and ARA - microbial fermentation

Aquagrow Gold

- *Schizochitrium sp.*

Aquagrow ARA

- *Mortierella alpine*



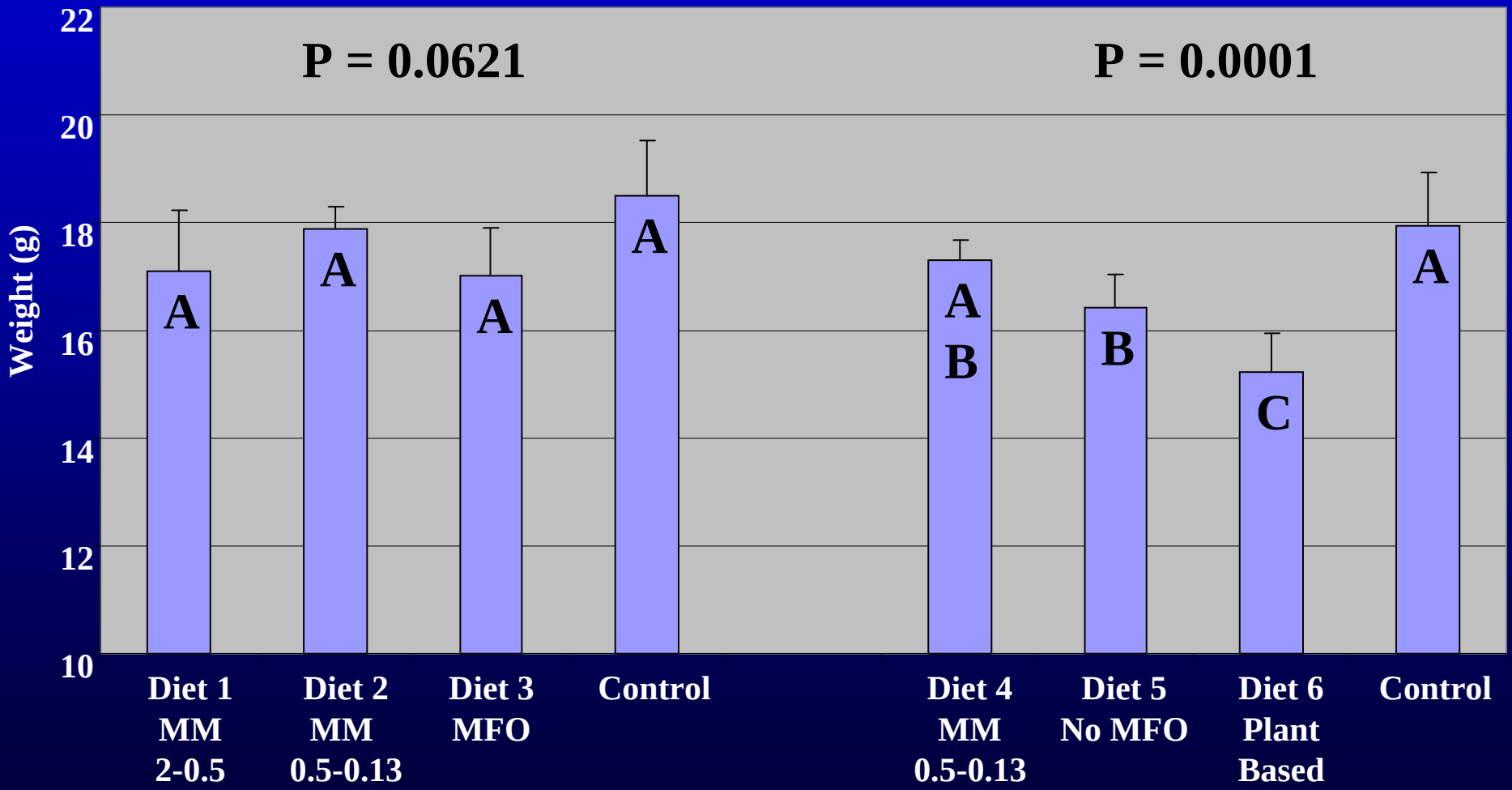
Other than fish, algae are the only source of DHA

Tank studies at TAES

- 650 l .85 m^2
- Shaded
- Aerated
- SPF *L. vannamei*
- 30 shrimp/m^2
- Water quality monitoring
- Oil from microbial fermentation products
- Profound™ co-extruded soybean and poultry by-product meal with egg supplement
- Organic plant protein sources

	Experiment I			Experiment II		
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
	AG2-0.5	AG0.5-0.13	Profound	AG0.5-0.13	w/o MFO	Organic
Profound™ [1]	39.00	39.00	39.00	39.00	39.00	
Soybean meal [2]	29.50	30.20	30.50	30.20	30.20	
Soybean meal, organic [3]						58.10
Field Pea Meal [4]						10.00
Corn gluten, organic [5]						9.00
Aqua Grow-Hi DHA [6]	2.00	0.50		0.50		0.50
AquaGrow ARA [6]	0.50	0.13		0.13		0.13
Kelp meal [7]						0.50
Menhaden Fish Oil [8]			3.04			
Soy oil [9]	1.47	1.53		1.53	1.30	
Soy oil, organic [10]						0.20
Flax oil (linseed oil) [11]	0.48	1.23		1.23	1.80	
Flax oil, organic [12]						2.00
Wheat starch [9]	1.98	2.34	2.39	2.34	1.63	
Whole wheat [9]	20.00	20.00	20.00	20.00	21.00	
Whole wheat-organic [10]						14.00
Trace Mineral premix	0.50	0.50	0.50	0.50	0.50	0.50
Vitamin premix	1.80	1.8	1.8	1.80	1.80	1.80
Choline chloride [9]	0.20	0.20	0.20	0.20	0.20	0.20
Stay C 250 mg/kg 14	0.07	0.07	0.07	0.07	0.07	0.07
CaP-diebasic [9]	2.00	2.00	2.00	2.00	2.00	2.00

Harvest data



Waddell Mariculture Center

Ingredients	Plant-Organic Percent by Weight	Poultry Percent by Weight
Expelled soybean meal, 42/7, organic	58.10	
Soybean meal solvent extracted		39.44
Whole soft wheat, organic	12.00	
Feed wheat		30.17
Pet food grade poultry by-product meal		12.00
Canadian feed pea meal, organic	10.00	
Non-GM corn gluten meal, 60% protein	9.00	8.00
Flaxseed oil	2.00	
Di-Calcium phosphate	2.00	1.92
Aqua-Bond-CM		1.38
Federal vitamin premix #30 w/o choline	1.80	0.50
UF premix- CO		2.00
Flax seed		
Squid liver meal	1.00	
Liquid fish solubles	1.00	
AquaGrow-schizochytrium-DHA®	0.50	
USFW #3 Mineral Mix	0.50	
Non-GM lecithin	0.50	0.50
BetaFin BT-Danisco	0.50	
Kelp meal, Acadian Seaplants Limited	0.50	
Wheat starch		
Soy oil, no additives, organic	0.20	3.68
Choline chloride, 70%	0.20	0.20
Cholesterol		
AquaGrow ARA®	0.13	
Aqua Min		0.15
Stay C 35%	0.07	0.07

Experimental design

- Six 0.1 HA ponds
- 0.8 g. nursed juveniles, 25/m^2
- Initial filling 400 um screen, fertilization
- No water exchange
- 89 days
- Weekly sampling
- Feed adjusted by growth and consumption
- Control 35% protein shrimp grower

Shrimp production results for fish meal based diet vs. organically certifiable plant based diet

Diet	Harvest size (g)*	Production (kg/ha)	Growth rate (g/wk)	Survival (%)	FCR
Commercial Diet	18.7 ± 0.7	4594 ± 102	1.0 ± 0.03	93 ± 3	1.4 ± 0.03
Plant Based Diet	19.2 ± 0.5	4592 ± 151	1.0 ± 0.05	88 ± 2	1.3 ± 0.03

Conclusions

- No significant differences in harvest weight, production, growth, survival or FCR
- Under conditions of the present trial, the fish meal and fish oil free, plant based diet supplemented with DHA and AA and very small amounts of squid meal and liquid fish solubles can be a fully equivalent shrimp production grow-out feed compared to conventional diet

Experimental design

- Six 0.1 HA ponds
- 1.4 g. nursed juveniles, 80/m^2
- Initial filling 400 um screen, fertilization
- Limited water exchange (2x20%)
- 91 days
- Weekly sampling
- Feed adjusted by growth and consumption
- Control 35% protein shrimp grower

Shrimp production results for fish meal based diet vs. poultry meal based diet

Diet	Harvest size (g)*	Production (kg/ha)	Growth rate (g/wk)	Survival (%)	FCR
Commercial Diet	14.0 ± 2.9	10,920 ± 672	0.97	72.4 ± 1.4	1.6 ± 0.2
Poultry Meal Based Diet	15.3 ± 2.7	11,723 ± 1,557	1.07	85.6 ± 13.2	1.7 ± 0.1

Conclusions

- Shrimp fed poultry meal based diet were larger than those fed the conventional diet
- No significant differences in harvest biomass, survival or FCR
- Under conditions of the present trial, the fish meal and fish oil free, poultry meal based diet produced results comparable to a conventional feed even at high stocking densities and production levels

Do the plant based fish meal, fish oil free shrimp diets produce an equivalent nutritional product from the human health perspective?

Fatty acid analyses were conducted for each test diet and on shrimp tail meat samples from each study.

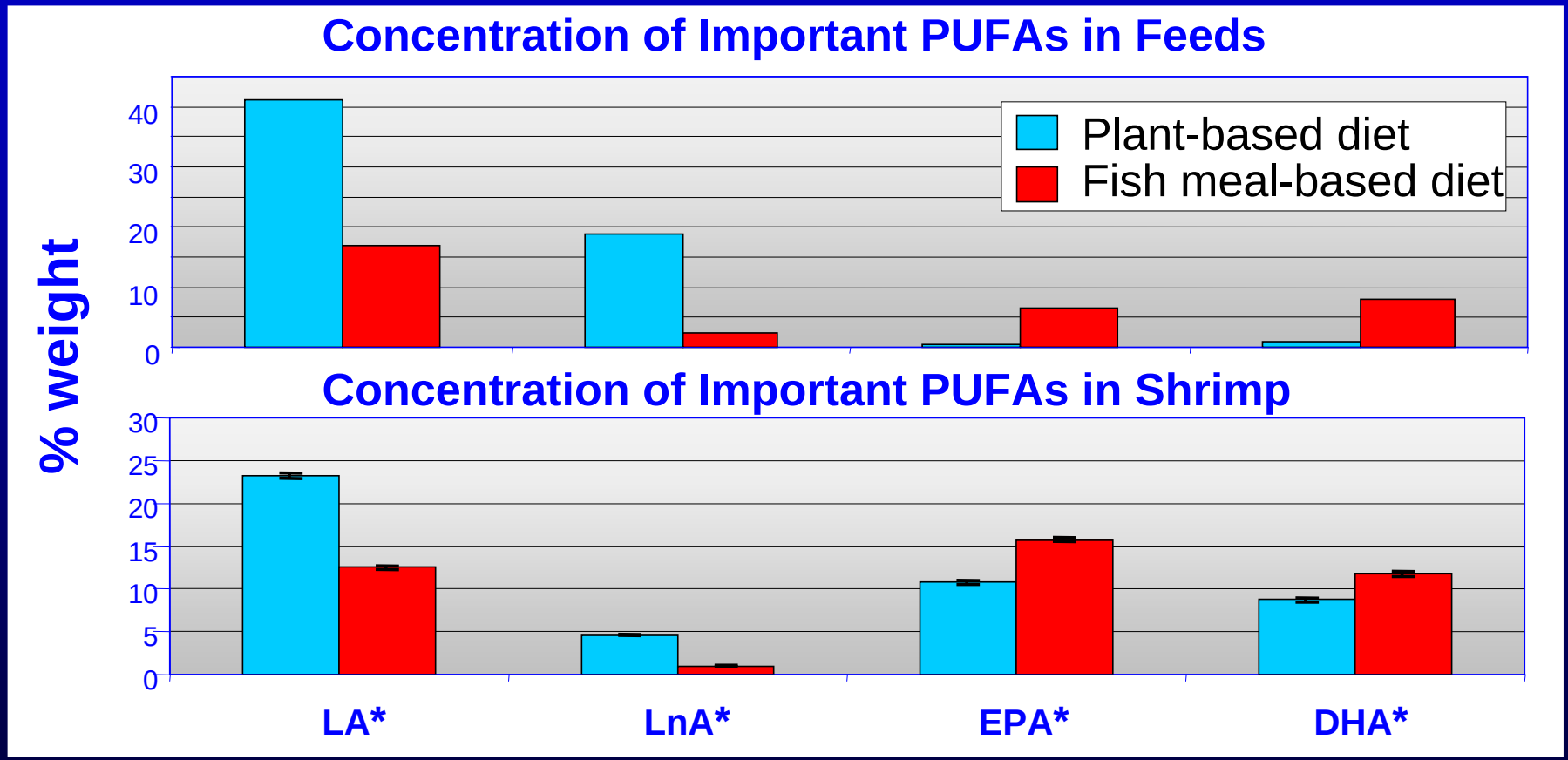
Analytical Scheme

- Lipid extraction
- Transesterification yielding fatty acid methyl esters (FAME)
- Separation and quantification of FAME by GC/MS
- Comparison of chromatograms of unknowns with those of voucher samples.

Shrimp nutritional quality
Plant based vs. conventional diet

- Differences in lipid profiles between the two diets in PUFA percentages
- LA and LnA significantly higher in shrimp fed plant-based diet
- AA , EPA and DHA significantly lower in shrimp fed plant-based diet
- Ratio of total n-6/n-3 fatty acids was 1.13 in shrimp fed the plant based diet compared to 0.58 in shrimp fed the fish meal based diet
- Primary contributing factor was incorporation of dietary LA (40% in plant based feed) resulting in a level in the shrimp of 23%

Lipid analysis



* denotes significant difference (P<0.05)

Conclusions

- Overall percent lipid in shrimp was equivalent for the two diets
- Mean lipid content of 1.0 % for the study shrimp, low fat to protein ratio
- EPA and DHA content was lower for the organic diet, but the shrimp (on a body weight equivalent basis) exceeded levels from USDA Nutritional Database (2005) for beef, pork, chicken
- Role of natural productivity in production performance and in lipid profiles to be determined

Experiments are underway to explore the role of natural productivity in improved ecologically based holistic approaches to organic shrimp farming

Bacteria

Cyanobacteria

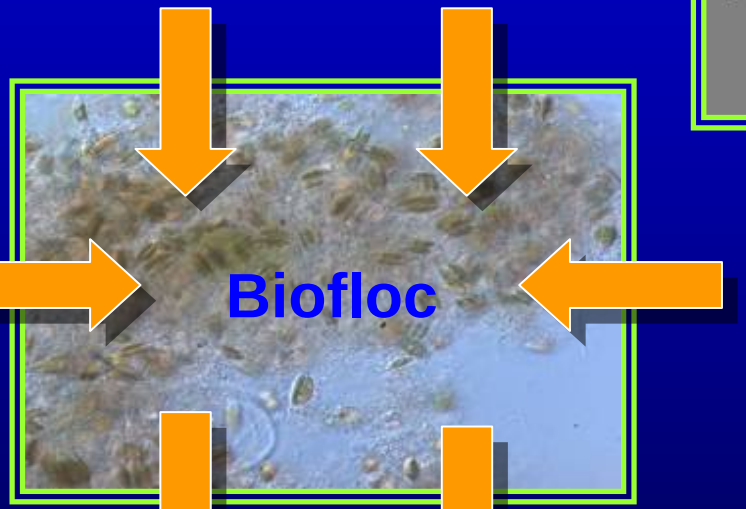
Green Algae

Diatoms

Dinoflagellates

Organic feeds

Shrimp wastes

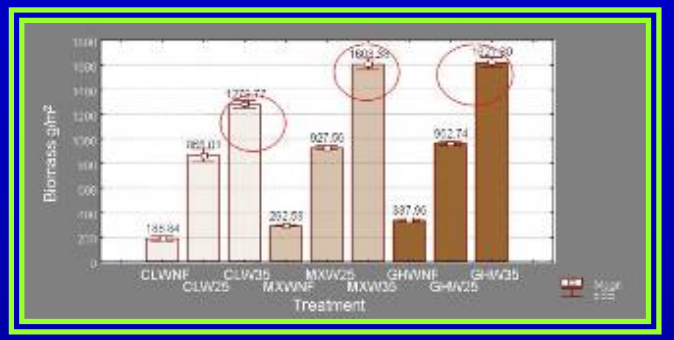


Supplemental nutrition

Fatty acids

Water quality

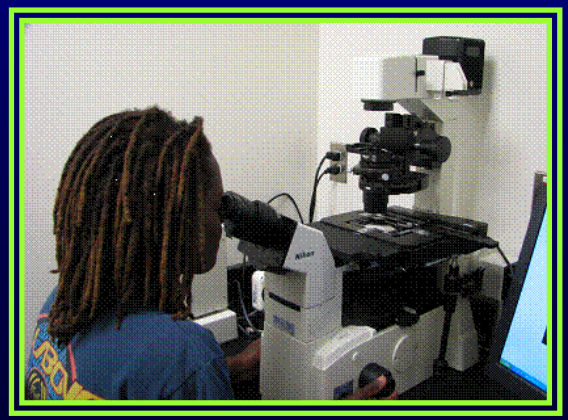
Waste cycling



Chemoautotrophs

Photoautotrophs

Heterotrophs



USDA certified organic shrimp

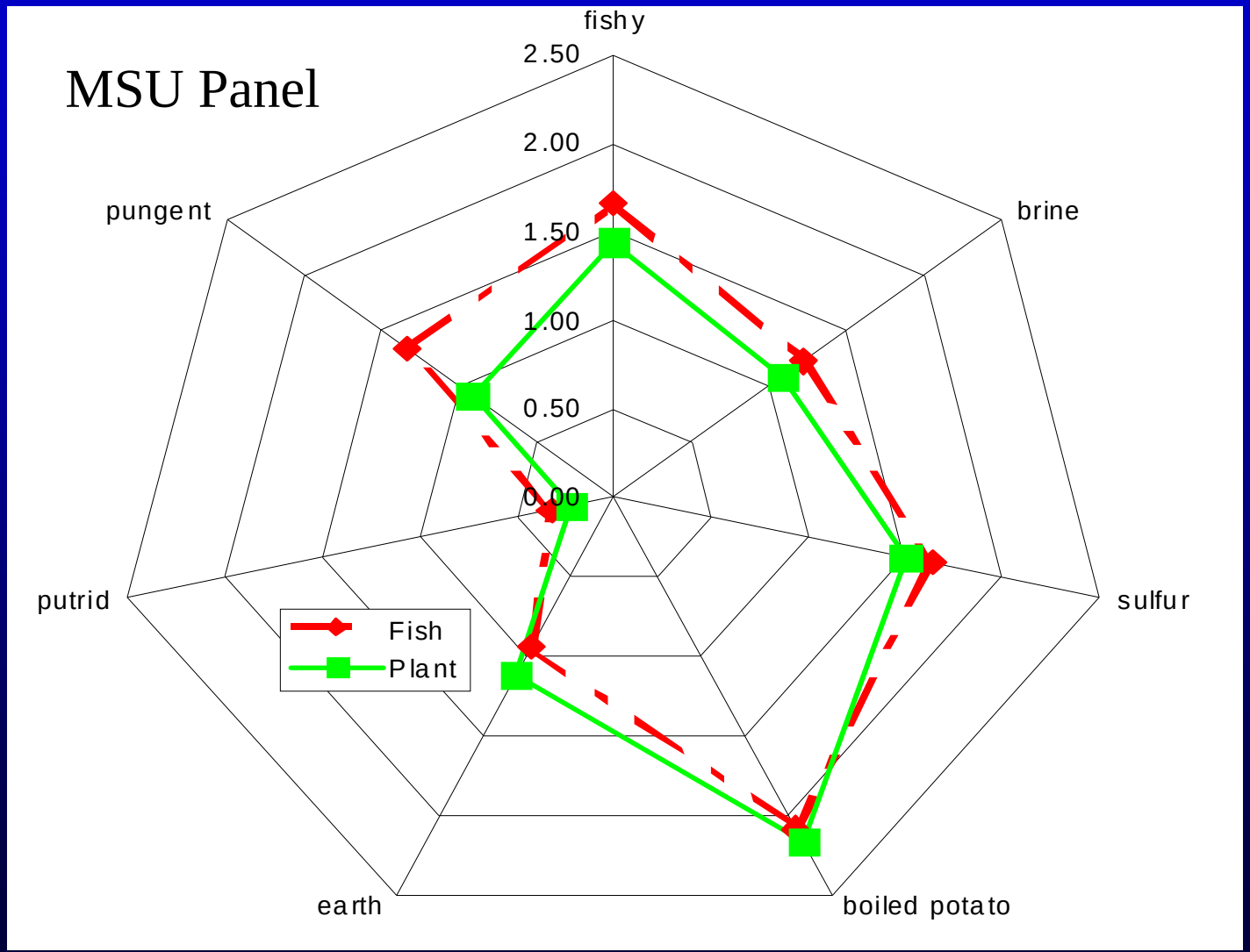
- Fish meal and oil can be removed from diets for marine shrimp *L. vannamei* without significantly reducing growth
- Terrestrial animal and plant proteins can be viable alternatives to meet marine protein requirements if amino acid balance is maintained
- Use of organically certifiable animal proteins in combination with vegetable based ingredients should be considered
- Replacement of marine oils will require an alternative HUFA source such as microbial meals to assure production performance and nutritional quality

Supplemental: Taste and texture data in response to NOSB question

Mississippi State Data

- ✓No statistical difference between FM/FO-grown shrimp and “Sustainable Shrimp”.
- ✓FM/FO-grown shrimp had stronger “fishy” and “pungent” flavor notes.
- ✓“Sustainable Shrimp” had more “sweet” and “earthy” flavor notes.

Taste and Texture ?



Taste and Texture ?