



**Potential Application of By-Products from  
Agriculture, Fisheries, and Biofuel Industries  
--- Nutrition and Toxicology Studies**

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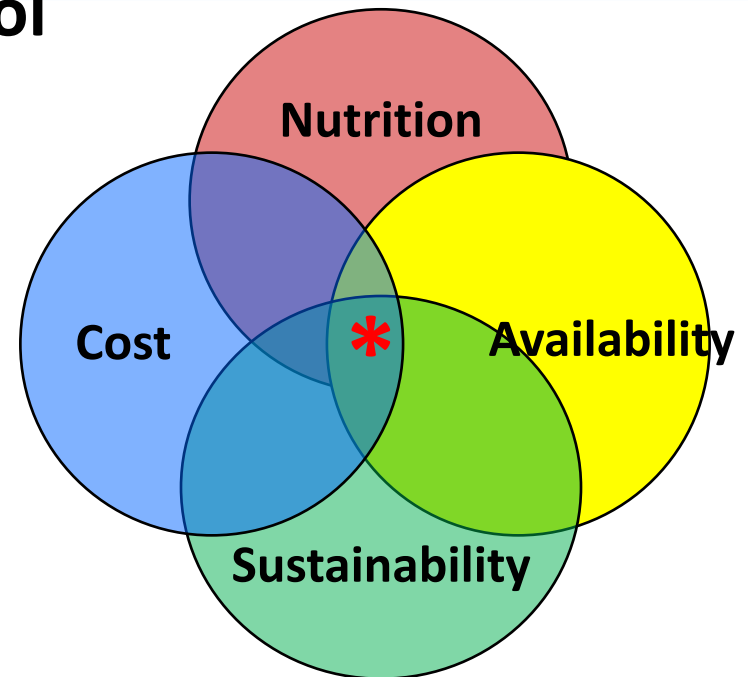
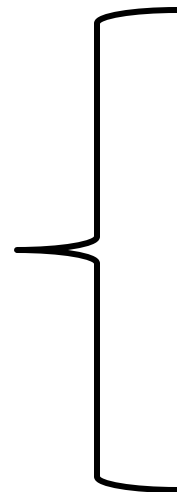
# Acknowledgements

- **Agricultural Research Service, United States  
Department of Agriculture**
- **National Institute of Food and Agriculture,  
United States Department of Agriculture**

# Optimal Feed for Sustainable Aquaculture

- Nutritional Studies
- Feed Processing Technology
- Analysis & Quality Control

**Optimal Feed**





**Sea Urchin**



**Opihi**

## **Nutritional Studies**

**---Nutrient requirement**

**---Alternative ingredients**



**Pacific Threadfin (Moi)**



**Pacific White Shrimp**



**Abalone**





**Palatability**



**Digestibility**



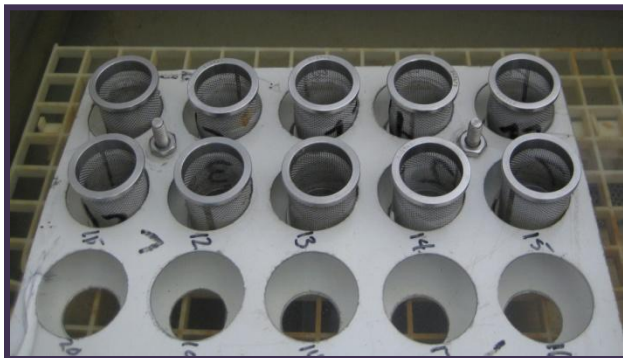
**Growth**



# Feed Processing Technology



## Physical quality of pellets



**Water stability**



**Pellet durability**

**Particle distribution**



## Quality Control Lab

- Ingredients
- Feeds
- Products

## Analysis

- Proximate composition (moisture, ash, crude protein and lipid)
- Gross energy
- Amino acids
- Fatty acids
- Vitamins and minerals
- Pigments



# Selection Criteria for an Ingredient

- 1. Chemical composition**
- 2. Effect on pellet physical quality**
- 3. Effects on attractiveness and palatability**
- 4. Effect on digestibility and growth performance**
- 5. Effect on product quality**
- 6. Availability and sustainability of production**



# Agriculture By-Product



**Coconut**

**Macadamia Nut**

**Papaya**

# Fishery By-Products



**Pollock**



**Arrowtooth flounder**

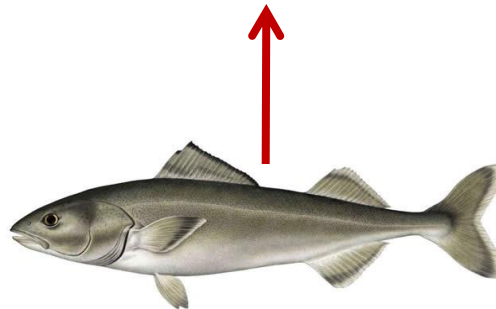


**Pink salmon**

**Head  
Skin  
Bone  
Milt  
Visceral  
Carapace**



**Tanner crab**



**Black cod**



# Biofuel By-Products



**Oil Seeds and Nuts**  
Algae, Coconut, Jatropha, Rapeseed, Camelina



**Processing**  
Clean Crack Extrude Press

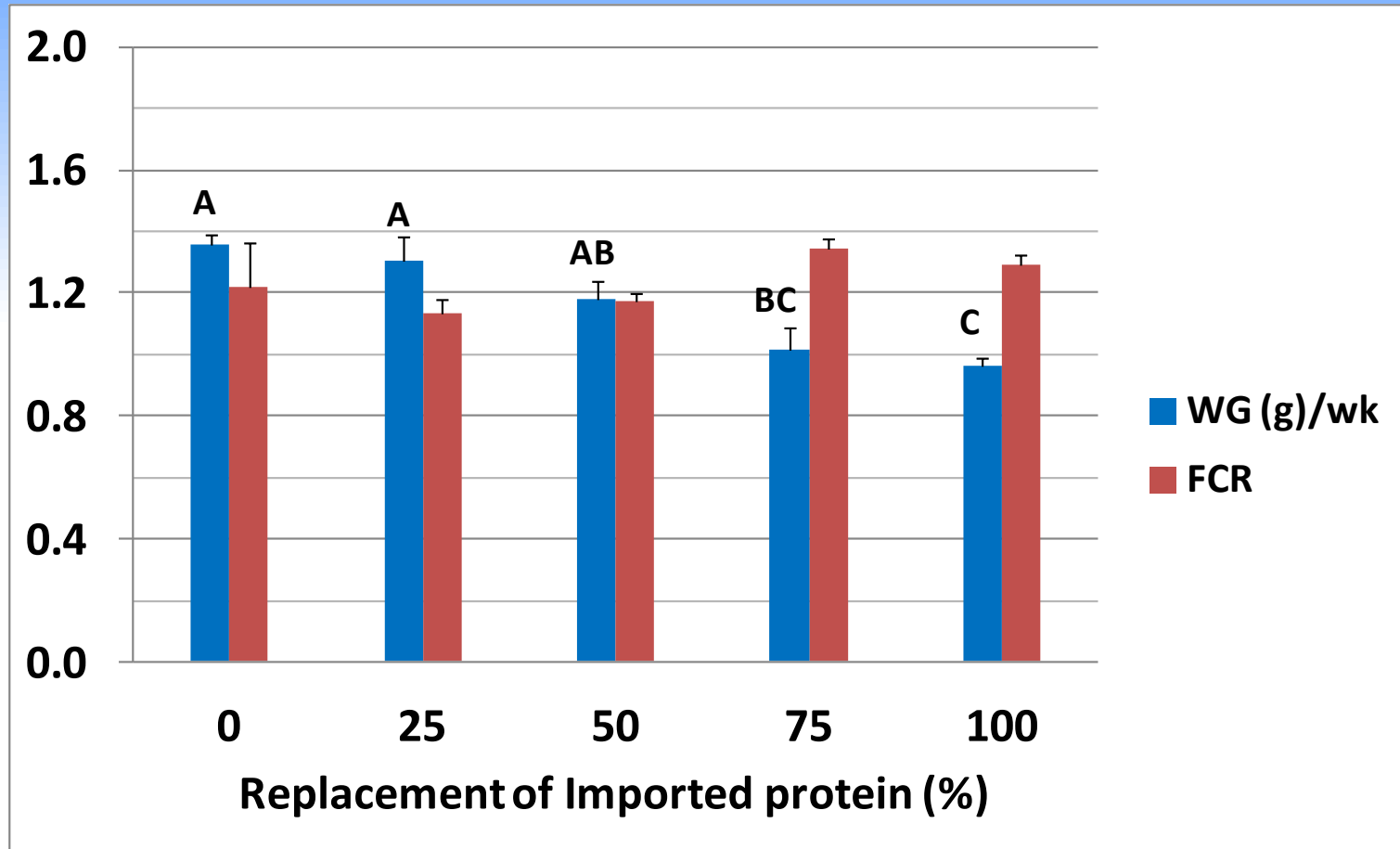


**Biodiesel**



**Feeds**

# Effect of Papaya Yeast on Growth Performance of Pacific White Shrimp





# Proximate Compositions of Fishery By-Products

Ingredient	Moisture	Protein	Lipid	Ash
		%		
<b>Menhaden meal</b>	<b>8.0</b>	<b>64.5</b>	<b>9.3</b>	<b>20.6</b>
<b>Soybean meal</b>	<b>6.7</b>	<b>48.3</b>	<b>1.9</b>	<b>7.2</b>
<b>Pollock Bone</b>	<b>12.8</b>	<b>38.1</b>	<b>4.1</b>	<b>41.2</b>
<b>Tanner Crab Carapace</b>	<b>4.9</b>	<b>35.9</b>	<b>8.7</b>	<b>28.2</b>
<b>Pink Salmon Livers</b>	<b>10.3</b>	<b>68.6</b>	<b>10.2</b>	<b>4.1</b>
<b>Pink Salmon Milt</b>	<b>8.5</b>	<b>86</b>	<b>3.0</b>	<b>12.5</b>
<b>Arrowtooth Heads &amp; Viscera</b>	<b>11.3</b>	<b>33.0</b>	<b>37.1</b>	<b>10.5</b>
<b>Black Cod Viscera</b>	<b>29.3</b>	<b>36.6</b>	<b>19.8</b>	<b>3.5</b>
<b>Dried Skate</b>	<b>7.2</b>	<b>87.6</b>	<b>1.8</b>	<b>11.8</b>
<b>Smoked Salmon Heads</b>	<b>3.0</b>	<b>57.6</b>	<b>27.6</b>	<b>10.9</b>

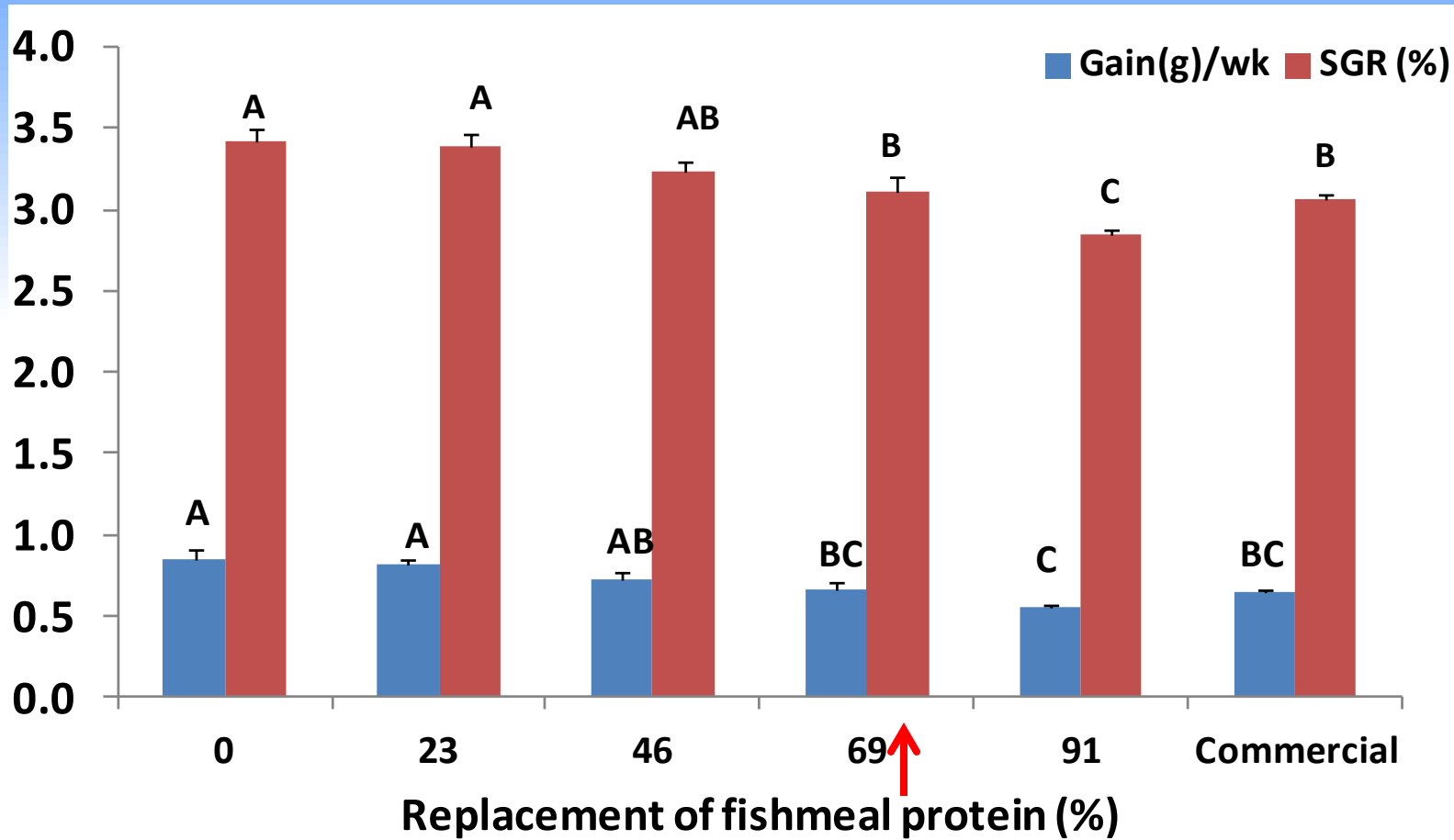
# Effect of Different By-Products on Palatability of Pacific White Shrimp



Ingredients	Stimulate Feeding
Pollock Bone	X
Tanner Crab Carapace	X
Pink Salmon Livers	✓
Pink Salmon Milt	✓
Arrowtooth Heads & Viscera	✓
Black Cod Viscera	✓
Dried Skate	✓
Smoked Fermented Salmon Heads	✓
Smoked Salmon Heads	X

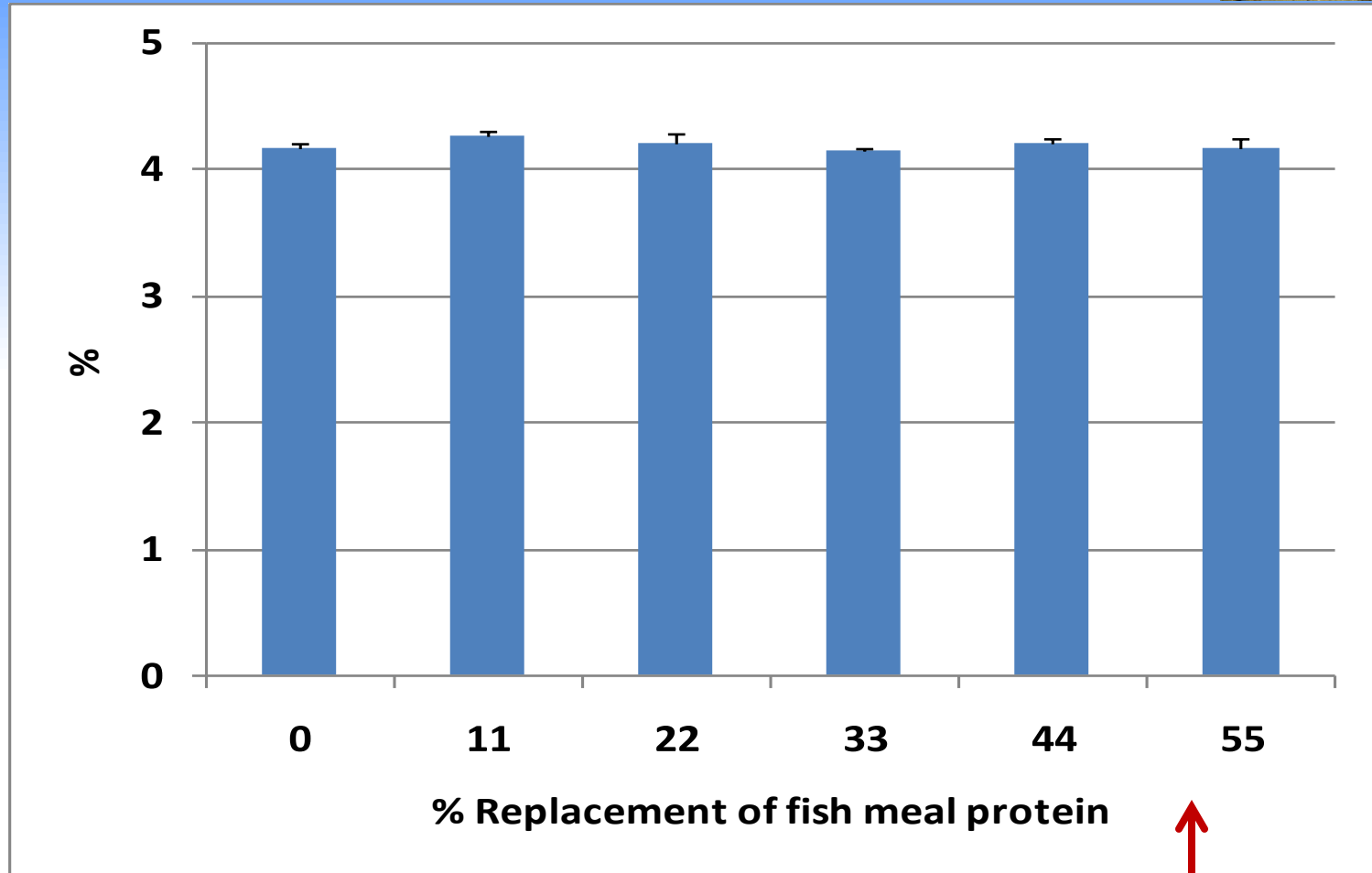
Basal diet: 75% soybean meal+25% wheat flour; test ingredient: 3-5%

# Effect of Salmon Milt on Growth Rate of Pacific White Shrimp



7.5% salmon milt +4.5% fishmeal+25% soybean meal

# Effect of Salmon Milt on Specific Growth Rate of Moi



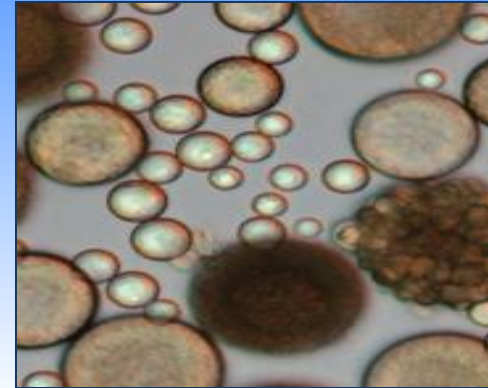
15% salmon milt +15% fishmeal+25% soybean meal



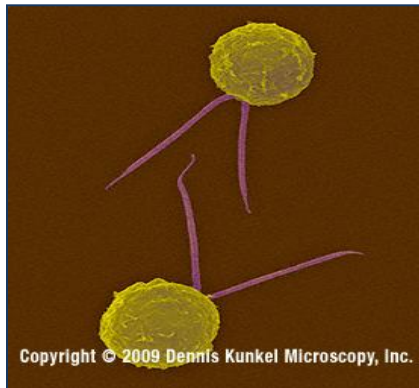
# Sources of Lipid/Long Chain PUFA



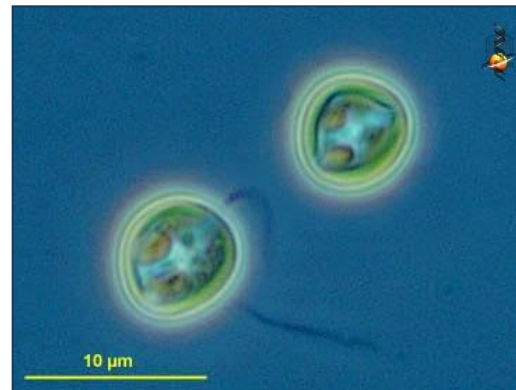
**Dinoflagellate alga (*Cryptothecodinium Cohnii*)**



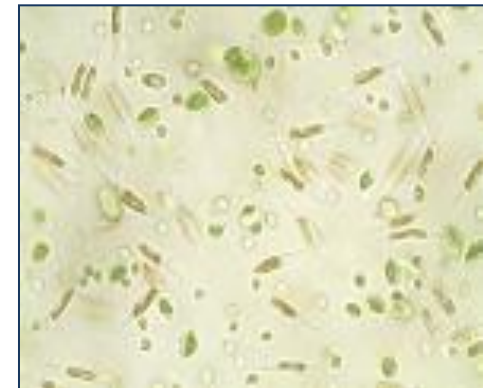
**Thraustochytrids (*schizochytrium*)**



***Isochrysis galbana***



***Pavlova lutheru***



***Nannochloropsis oculata***

# Fatty Acids Profiles of Different Ingredients

## (% of Total Fatty Acids)

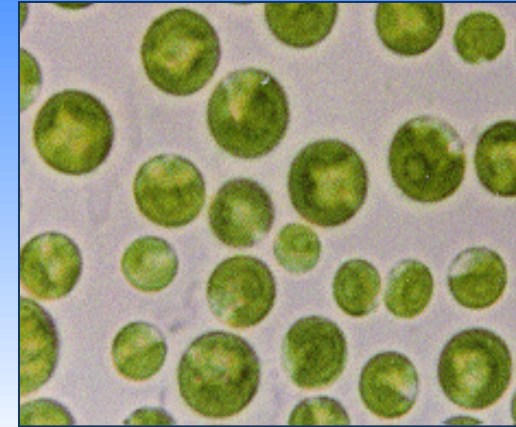
Ingredients	18:2n-6	18:3n-3	20:4n-6	20:5n-3	22:6n-3	Chol.
Menhaden oil	1.3	0.3	0.2	<b>11</b>	<b>9.1</b>	<b>0.52</b>
Cod liver oil	1.4	0.6	1.6	<b>11.2</b>	<b>12.6</b>	<b>0.57</b>
Tallow oil	3.1	0.6	---	---	---	0.1
Soybean oil	51	6.8	---	---	---	---
Corn oil	58	0.7	---	---	---	---
Chaetoceros sp	1	0.4	3	<b>16.7</b>	<b>0.8</b>	
Pavlova lutheri	2.1	2.1	0.5	<b>28.3</b>	<b>15.5</b>	
Isochrysis galbana	8.6	4.5	---	<b>0.9</b>	<b>19.4</b>	
Cryptomonas sp	0.6	25.1	0.2	<b>12</b>	<b>6.6</b>	
Rhodomonas sp	1.9	25.2	---	<b>8.7</b>	<b>4.6</b>	
Schizochytrium sp	0.7	0.11	2.9	<b>0.6</b>	<b>31.4</b>	

**Chol, cholesterol, % of diet**

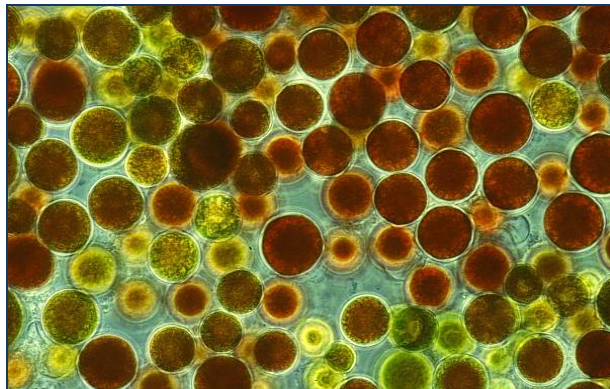
# Nutritional Pigments



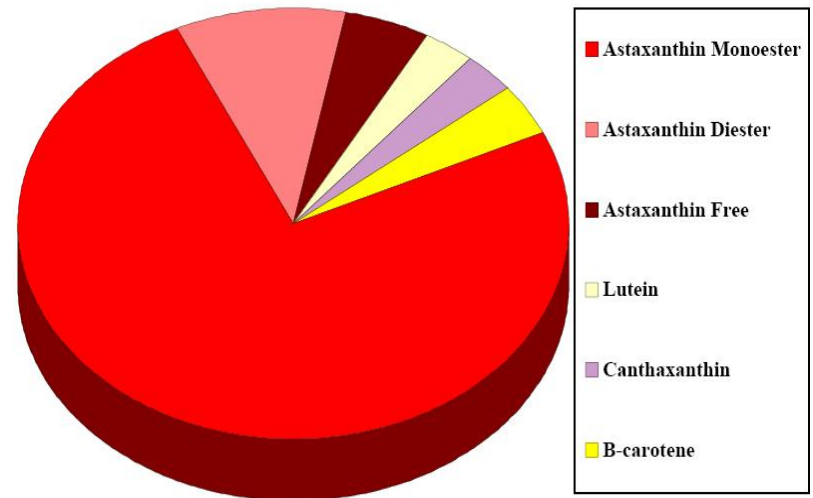
**Dunaliella Salina produces  $\beta$ -carotene**



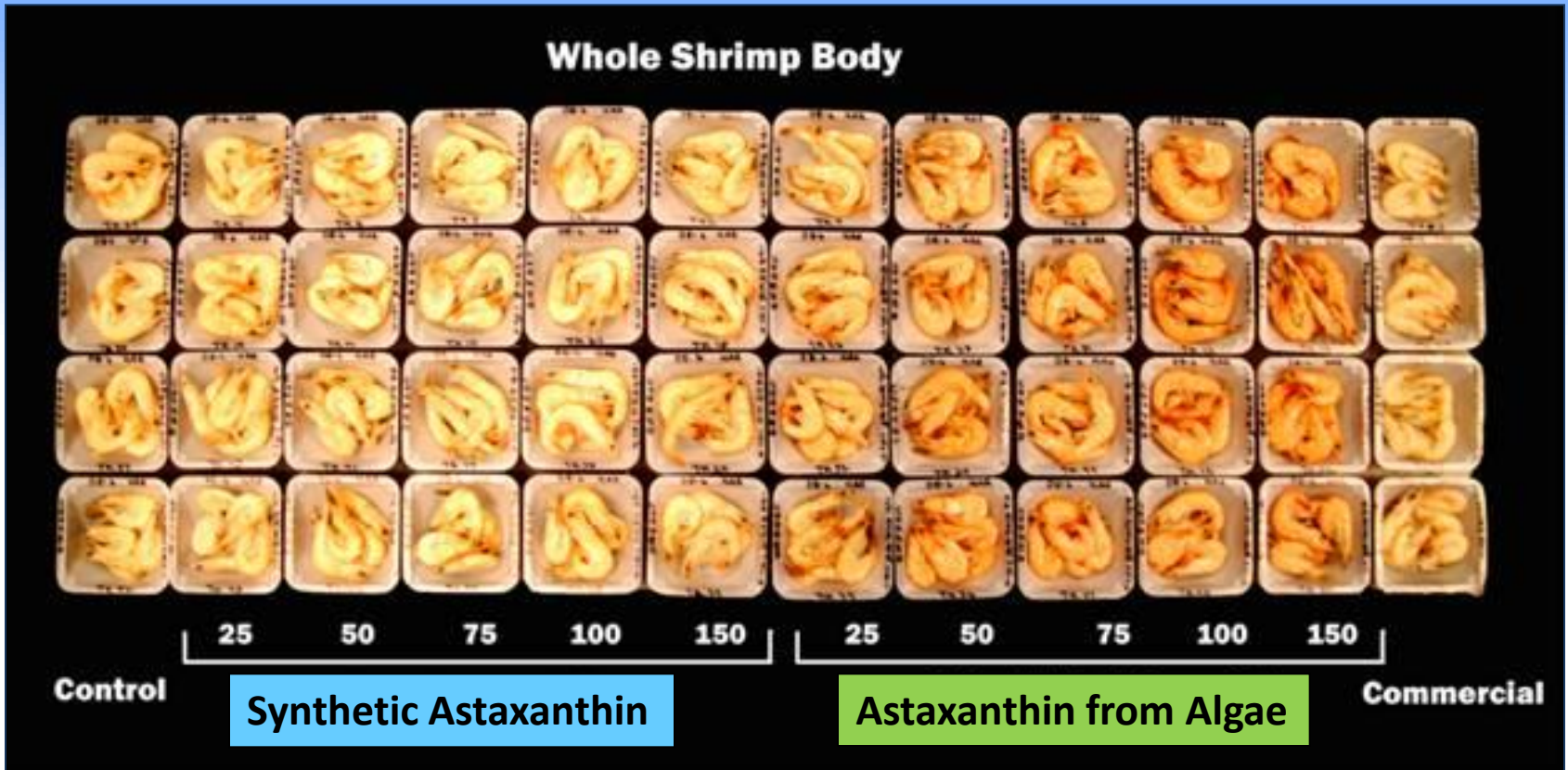
**Chlorella produces lutein and astaxanthin**



**Haematococcus produces mixed carotenoids**



# Astaxanthin Improves Pigmentation in Shrimp





# Application of By-Products in Aquatic Feeds

## Opportunities

- Substitute imported protein ingredients
- Enhance feed utilization as feed additives
- Improve product quality

## Concerns

- Levels of nutrients and toxins
- Effect on final product quality
- Production and cost of a by-product
- Optimal processing methods

# Toxicology Study

## Application of Organic Compounds From Biodiesel Co-Product To Control Apple Snail (*P. Canaliculata*) On Wetland Taro

Pacific Biodiesel, Inc. Kahului, HI 96732

Oceanic Institute

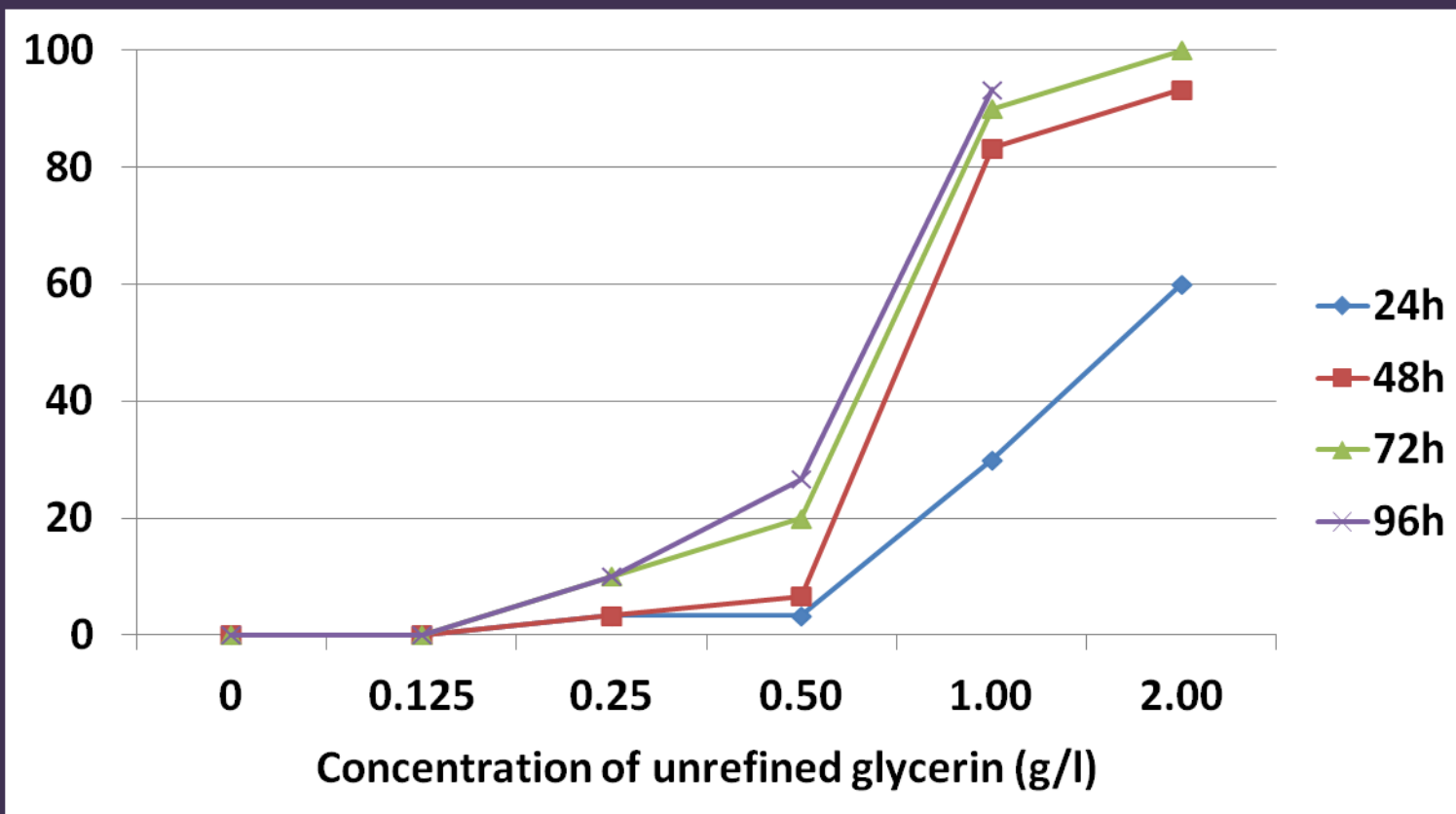
Pacific Biodiesel Technologies, LLC.

Hawaii Land Restoration Institute

Taro Farmers



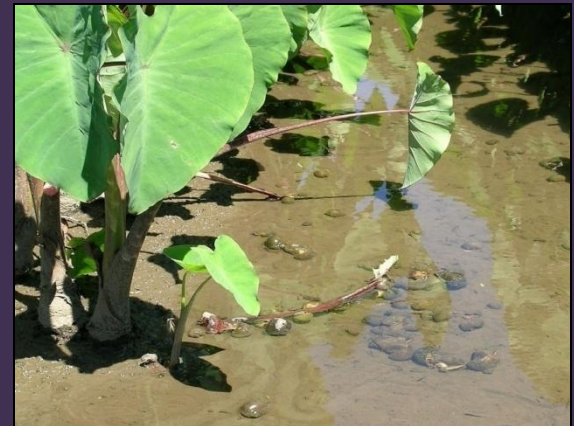
# Mortality of Apple Snail Exposed to the Unrefined Co-Product



Exposure Period (h)	24	48	72	96
<b>LC50 (g/l)</b>	<b>1.59</b>	<b>0.77</b>	<b>0.62</b>	<b>0.60</b>

# Future Studies

- Identify other active compounds in the co-product;
- Investigate effect of the active compounds on non-target species;
- Determine effective concentration of the co-product in field trials





# MAHALO!



**Oceanic Institute**  
An Affiliate of Hawai'i Pacific University

# Comparison of Ingredient Costs

Ingredient	Crude protein (%)	Cost (\$)/Mt	Cost (\$)/kg protein
<b>Fishmeal</b>	<b>68</b>	<b>1500</b>	<b>2.21</b>
Soybean meal	48	400	0.83
Corn gluten meal	60	635	1.06
Pork blood meal	90	880	0.98
Pork meat and bone meal	50	435	0.87
Cotton seed meal	41	374	0.94
Canola meal	36	253	0.70

# Identification of the Active Compounds in the Unrefined Co-Product

