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

![Venn Diagram showing overlap of Nutrition, Cost, Sustainability, and Availability with an asterisk on Availability]
Nutritional Studies
---Nutrient requirement
---Alternative ingredients

Pacific Threadfin (Moi)
Pacific White Shrimp
Abalone
Palatability

Digestibility

Growth
Feed Processing Technology

Research feed mill

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
- Tanner crab
- Black cod

Head
Skin
Bone
Milt
Visceral
Carapace
Biofuel By-Products

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

Processing
Clean Crack Extrude Press

Oil
Biodiesel

Feeds
Effect of Papaya Yeast on Growth Performance of Pacific White Shrimp
# Proximate Compositions of Fishery By-Products

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Moisture</th>
<th>Protein</th>
<th>Lipid</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Menhaden meal</strong></td>
<td>8.0</td>
<td>64.5</td>
<td>9.3</td>
<td>20.6</td>
</tr>
<tr>
<td><strong>Soybean meal</strong></td>
<td>6.7</td>
<td>48.3</td>
<td>1.9</td>
<td>7.2</td>
</tr>
<tr>
<td><strong>Pollock Bone</strong></td>
<td>12.8</td>
<td>38.1</td>
<td>4.1</td>
<td>41.2</td>
</tr>
<tr>
<td><strong>Tanner Crab Carapace</strong></td>
<td>4.9</td>
<td>35.9</td>
<td>8.7</td>
<td>28.2</td>
</tr>
<tr>
<td><strong>Pink Salmon Livers</strong></td>
<td>10.3</td>
<td>68.6</td>
<td>10.2</td>
<td>4.1</td>
</tr>
<tr>
<td><strong>Pink Salmon Milt</strong></td>
<td>8.5</td>
<td>86</td>
<td>3.0</td>
<td>12.5</td>
</tr>
<tr>
<td><strong>Arrowtooth Heads &amp; Viscera</strong></td>
<td>11.3</td>
<td>33.0</td>
<td>37.1</td>
<td>10.5</td>
</tr>
<tr>
<td><strong>Black Cod Viscera</strong></td>
<td>29.3</td>
<td>36.6</td>
<td>19.8</td>
<td>3.5</td>
</tr>
<tr>
<td><strong>Dried Skate</strong></td>
<td>7.2</td>
<td>87.6</td>
<td>1.8</td>
<td>11.8</td>
</tr>
<tr>
<td><strong>Smoked Salmon Heads</strong></td>
<td>3.0</td>
<td>57.6</td>
<td>27.6</td>
<td>10.9</td>
</tr>
</tbody>
</table>
Effect of Different By-Products on Palatability of Pacific White Shrimp

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Stimulate Feeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pollock Bone</td>
<td>X</td>
</tr>
<tr>
<td>Tanner Crab Carapace</td>
<td>X</td>
</tr>
<tr>
<td>Pink Salmon Livers</td>
<td>✓</td>
</tr>
<tr>
<td>Pink Salmon Milt</td>
<td>✓</td>
</tr>
<tr>
<td>Arrowtooth Heads &amp; Viscera</td>
<td>✓</td>
</tr>
<tr>
<td>Black Cod Viscera</td>
<td>✓</td>
</tr>
<tr>
<td>Dried Skate</td>
<td>✓</td>
</tr>
<tr>
<td>Smoked Fermented Salmon Heads</td>
<td>✓</td>
</tr>
<tr>
<td>Smoked Salmon Heads</td>
<td>X</td>
</tr>
</tbody>
</table>

Basal diet: 75% soybean meal + 25% wheat flour; test ingredient: 3-5%
Effect of Salmon Milt on Growth Rate of Pacific White Shrimp

Replacement of fishmeal protein (%)

Gain(g)/wk  SGR (%)

0.0  0.5  1.0  1.5  2.0  2.5  3.0  3.5  4.0

Commerical

7.5% salmon milt +4.5% fishmeal+25% soybean meal
Effect of Salmon Milt on Specific Growth Rate of Moi

% Replacement of fish meal protein

15% salmon milt +15% fishmeal+25% soybean meal
Sources of Lipid/Long Chain PUFA

- Dinoflagellate alga (Crypthecodinium *Cohnii*)
- Thraustochytrids (schizochytrium)
- *Isochrysis galbana*
- *Pavlova lutheru*
- *Nannochloropsis occulata*
### Fatty Acids Profiles of Different Ingredients

(\% of Total Fatty Acids)

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

Chol, cholesterol, \% of diet
Nutritional Pigments

Dunaliella Salina produces β-carotene

Chlorella produces lutin and astaxanthin

Haematococcus produces mixed carotenoids

http://www.themagicisbac.com/
Astaxanthin Improves Pigmentation in Shrimp

Ju et al. 2011
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

<table>
<thead>
<tr>
<th>Exposure Period (h)</th>
<th>24</th>
<th>48</th>
<th>72</th>
<th>96</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC50 (g/l)</td>
<td>1.59</td>
<td>0.77</td>
<td>0.62</td>
<td>0.60</td>
</tr>
</tbody>
</table>
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
ALOHA!

MAHALO!
## Comparison of Ingredient Costs

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Crude protein (%)</th>
<th>Cost ($)/Mt</th>
<th>Cost ($)/kg protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fishmeal</td>
<td>68</td>
<td>1500</td>
<td>2.21</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>48</td>
<td>400</td>
<td>0.83</td>
</tr>
<tr>
<td>Corn gluten meal</td>
<td>60</td>
<td>635</td>
<td>1.06</td>
</tr>
<tr>
<td>Pork blood meal</td>
<td>90</td>
<td>880</td>
<td>0.98</td>
</tr>
<tr>
<td>Pork meat and bone meal</td>
<td>50</td>
<td>435</td>
<td>0.87</td>
</tr>
<tr>
<td>Cotton seed meal</td>
<td>41</td>
<td>374</td>
<td>0.94</td>
</tr>
<tr>
<td>Canola meal</td>
<td>36</td>
<td>253</td>
<td>0.70</td>
</tr>
</tbody>
</table>
Identification of the Active Compounds in the Unrefined Co-Product