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

"From feed to farm to fork"

- Ingredient supplier
  - Fish Meal
  - Soybean
  - Fish Oil
  - Other
  - Minerals
  - Vitamins

- FEED FACTORY
  - Feed Production

- FARM
  - Aquaculture Production

- PROCESSOR
  - Processing
  - Food Manufacture

- RETAILER
  - Exports
  - Open-Air Markets
  - Super-Markets
  - Restaurants

FOOD SAFETY
- Antibiotics
- Antibiotic growth promoters
- Traceability
- GMO
- HACCP
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 – H₂O

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  B₁  B₂  B₆  Pa  Ni  Bio

B₁₂  Fo  Ch  In  C

Score = 38/45 (unchanged from 2014)

Glencross 2015 TARS

Aqua Division
Stress and energy requirement

<table>
<thead>
<tr>
<th>Shrimp size (g)</th>
<th>Protein (%)</th>
<th>Lipid (%)</th>
<th>Cholesterol (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0-0.5</td>
<td>45%</td>
<td>7.5%</td>
<td>0.40%</td>
</tr>
<tr>
<td>0.5-3.0</td>
<td>40%</td>
<td>6.7%</td>
<td>0.35%</td>
</tr>
<tr>
<td>3.0-15</td>
<td>38%</td>
<td>6.3%</td>
<td>0.30%</td>
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<tr>
<td>15-40</td>
<td>36%</td>
<td>6.0%</td>
<td>0.25%</td>
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</tbody>
</table>

Tacon, 2002
## Product Specification

### NUTRITION COMPOSITION OF FEED

<table>
<thead>
<tr>
<th>Feed Code</th>
<th>Feed Type</th>
<th>Protein (Mn. %)</th>
<th>Fat (Mn. %)</th>
<th>Fiber (Max. %)</th>
<th>Ash (Max. %)</th>
<th>Moisture (Max. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KJV 1</td>
<td>Crumble</td>
<td>37</td>
<td>5</td>
<td>2</td>
<td>13</td>
<td>11</td>
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<tr>
<td>KJV 2A</td>
<td>Crumble</td>
<td>37</td>
<td>5</td>
<td>2</td>
<td>13</td>
<td>11</td>
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<tr>
<td>KJV 2B</td>
<td>Crumble</td>
<td>37</td>
<td>5</td>
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<td>11</td>
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<tr>
<td>KJV 3S</td>
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<td>33</td>
<td>5</td>
<td>2</td>
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<td>11</td>
</tr>
<tr>
<td>KJV 3M</td>
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<td>33</td>
<td>5</td>
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<td>13</td>
<td>11</td>
</tr>
<tr>
<td>KJV 3L</td>
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<td>33</td>
<td>5</td>
<td>2</td>
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<td>11</td>
</tr>
<tr>
<td>KJV 4</td>
<td>Pellet</td>
<td>33</td>
<td>5</td>
<td>2</td>
<td>13</td>
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</table>

### Feed No.

<table>
<thead>
<tr>
<th>Item</th>
<th>PL-1</th>
<th>PL-2</th>
<th>PL-3</th>
<th>STARTER</th>
<th>GROWER</th>
<th>FINISHER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed Form</td>
<td>Crumble</td>
<td>Crumble</td>
<td>Crumble</td>
<td>Pellet</td>
<td>Pellet</td>
<td>Pellet</td>
</tr>
<tr>
<td>Feed size (mm)</td>
<td>0.5 ~ 1.2</td>
<td>1.2 ~ 2.2</td>
<td>1.6, 1.2~3</td>
<td>1.8, 1.2~4</td>
<td>2.0, 1.3~5</td>
<td>2.2, 1.4~6</td>
</tr>
<tr>
<td>Shrimp size (g)</td>
<td>PL 15 ~ 35</td>
<td>PL 35 ~ 5 g</td>
<td>PL 35 ~ 5 g</td>
<td>5 ~ 8 g</td>
<td>15 ~ 25 g</td>
<td>25 g up</td>
</tr>
<tr>
<td>Crude Protein (no less than)</td>
<td>40%</td>
<td>40%</td>
<td>40%</td>
<td>38%</td>
<td>38%</td>
<td>37%</td>
</tr>
<tr>
<td>Crude Fat (no less than)</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Fiber (not more than)</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Moisture (not more than)</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Ash (not more than)</td>
<td>15%</td>
<td>15%</td>
<td>15%</td>
<td>15%</td>
<td>15%</td>
<td>15%</td>
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<tr>
<td>Hydrochloric Insoluble (not more than)</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
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</table>

## Code

<table>
<thead>
<tr>
<th>Code</th>
<th>Packaging (kg)</th>
<th>Type</th>
<th>Protein (min. %)</th>
<th>Fat (min. %)</th>
<th>Fiber (max. %)</th>
<th>Ash (max. %)</th>
<th>Moisture (max. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT3S</td>
<td>10</td>
<td>Pellet</td>
<td>30</td>
<td>5</td>
<td>4</td>
<td>11</td>
<td>11</td>
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<tr>
<td>NT3M</td>
<td>25</td>
<td>Pellet</td>
<td>30</td>
<td>5</td>
<td>4</td>
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<tr>
<td>NT3L</td>
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<td>Pellet</td>
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<td>4</td>
<td>11</td>
<td>11</td>
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<tr>
<td>NT4</td>
<td>25</td>
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<td>28</td>
<td>5</td>
<td>4</td>
<td>11</td>
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## NUTRITIONS

<table>
<thead>
<tr>
<th>PRODUCT CODE</th>
<th>VANA 1</th>
<th>VANA 2</th>
<th>VANA 3</th>
<th>VANA 3P</th>
<th>VANA 4</th>
<th>VANA 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Protein (% min)</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Crude Fat (%)</td>
<td>5~7</td>
<td>5~7</td>
<td>5~7</td>
<td>5~7</td>
<td>5~7</td>
<td>5~7</td>
</tr>
<tr>
<td>Crude Fiber (% max)</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Crude Ash (% max)</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Moisture (% max)</td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>11</td>
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</tr>
<tr>
<td>Diameter (mm)</td>
<td>0.1~0.2</td>
<td>0.2~0.6</td>
<td>0.3~0.5</td>
<td>0.2~0.6</td>
<td>1.6~1.8</td>
<td>1.6~1.8</td>
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</table>

Results from Internet search
Nutritional value of aquafeed

<table>
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<tr>
<th>Nutrient</th>
<th>Analysis</th>
<th>Analysis</th>
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<tr>
<td>DM</td>
<td>89.681987</td>
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<tr>
<td>CP</td>
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<td>38.996968</td>
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<td>EE</td>
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<td>7.739536</td>
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<tr>
<td>CF</td>
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<td>1.176603</td>
</tr>
<tr>
<td>ASH</td>
<td>12.464193</td>
<td>11.925501</td>
</tr>
<tr>
<td>MOI</td>
<td>10.091832</td>
<td>10.146957</td>
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<tr>
<td>CA</td>
<td>1.645472</td>
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<td>P</td>
<td>1.393126</td>
<td>1.379654</td>
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<td>CA:P</td>
<td>1.181136</td>
<td>1.111856</td>
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<tr>
<td>NA</td>
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<td>K</td>
<td>0.23175</td>
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<td>GE</td>
<td>4099.012306</td>
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<td>LYS</td>
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<td>MET</td>
<td>0.899979</td>
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<td>M+C</td>
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<td>CYS</td>
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<td>THR</td>
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<td>TRY</td>
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<td>VAL</td>
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<td>PHE</td>
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</tr>
<tr>
<td>STARCH</td>
<td>17.449887</td>
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</tr>
<tr>
<td>CHOLINE</td>
<td>13.11766</td>
<td>13.128488</td>
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</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Raw materials</th>
<th>Protein source</th>
<th>Energy source</th>
<th>Lipid source</th>
<th>Unsat. fatty acids</th>
<th>Phospholipids</th>
<th>Cholesterol</th>
<th>Vitamin source</th>
<th>Mineral source</th>
<th>Growth promoters</th>
<th>Pigment source</th>
<th>Attractant</th>
<th>Binder (waterstability)</th>
<th>Improving preservation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish meal</td>
<td>+++</td>
<td>++</td>
<td>(+)</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>+</td>
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<td>++</td>
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<tr>
<td>Wheat flour</td>
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<td>++</td>
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<td>+</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Corn Gluten meal</td>
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<td>++</td>
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<td>+</td>
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<td>Shrimp shell meal</td>
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<tr>
<td>Squid by-product meal</td>
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<td>Squid oil</td>
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<td>Lecithin</td>
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<td>Vitamin premix</td>
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<td>Mineral premix</td>
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<td>+</td>
<td>++</td>
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<td>++</td>
</tr>
<tr>
<td>Anti-mold &amp; Anti-oxidant</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>++</td>
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<td>+</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Improving preservation</td>
<td>-</td>
<td>++</td>
<td>-</td>
<td>++</td>
<td>++</td>
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</tr>
</tbody>
</table>

Legend: + indicates positive effect, - indicates negative effect

---

**ROLE OF INGREDIENTS**

- **Protein source**: 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
- **Energy source**: 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
- **Lipid source**: 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
- **Unsaturated fatty acids**: 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
- **Phospholipids**: 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
- **Cholesterol**: 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
- **Vitamin source**: 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
- **Mineral source**: 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
- **Growth promotors**: 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
- **Pigment source**: 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
- **Attractant**: 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
- **Binder (waterstability)**: 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
- **Improving preservation**: 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

---

**Legend:**
- (+) indicates potential positive effect
- (-) indicates potential negative effect
Nutrient composition of Selected Protein sources in *L. vannamei*

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

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

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

(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).
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

- B fail
- C pass
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

- Dumping
  - Coarse RM
  - Fine RM
- Pre-Grinding
- Pre-Mixing
- Pulverizing
- Post-Mixing
- Pre-Conditioning
- Pelleting
- Post-Conditioning
- Drying
- Cooling
- Screening
- Pellet Packing
- Crumbling
- Screening
- Crumble Packing

QC Checks and Sampling during processing
Old Challenges

- Farm environment
- Disease
- Feed quality
- Fry quality
- Farm Management

FARM HARVEST

Production costs
Fluctuating price

FARM PROFIT
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

Aqua Division
Pond water quality during production

COD Changes over time

Nitrite-N Changes over time

Total Ammonia Changes over time

Species: *P. monodon*

Stocking density – 60 - 100PL/m²
Species: *P. monodon*

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

High stocking density
- 98 PL/m²
- 9 t/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.
Stress and energy requirement

Exposure to high level of NH3 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 NH3 (Miranda-Filho et al, 2009), affecting availability of dietary energy.
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), ).
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
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.
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)
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.
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