تقييم أداء الربيان الأبيض الهندي Fenneropenaeus indicus المストレス في نظام إعادة تدوير مياه التربة

المستخلاص

قام المركز بالتفحص عن مدى إمكانية تربية الربيان الأبيض Fenneropenaeus indicus بإعادة تدوير المياه. وفي هذا الجانب تم تنفيذ تجربتين خلال الفترة الممتدة من يونيو وحتى ديسمبر 2016. تمت التحريج الأولى في تقديم أداء الربيان عن طريق التحول في النغمة من علبية بادئة 3 إلى علبية خاصة بالتسمين. مع بلوغ الربيان لطور ما بعد يرقي 117، على الرغم من إحتواء كلا العلبتين المتفاوتتين في الحجم على نفس المكونات الغذائية، إلا أن المجموعة المثلثة لعلبية بادئة-3 أظهرت أداء أفضل من حيث معدلات النمو، ونهاية وزن، معدلات النمو الوراثي، بما فيه نسبة التحول الغذائي والانتاجية بالمقارنة مع المجموعة المثلثة لعلبية تسمين 1-1 إبتداءا لأطوار ما بعد يرقي 117 وحتى 216. وربما يمكن أن تكون نتائج الرضا بين المجموعتين إلى بعض العناصر المغلقة في العلبية البادئة-1 في الأساس. بالنسبة للتجربة الثانية، فقامت في تقديم أداء نمو الربيان وفقا لمعدلات التخزين باء على أجمال مستقبلات وأخرى متماثلة في الحجم من الأطوار ما بعد أربكة. أظهرت النتائج إحراز المجموعة المتماثلة في الحجم من الأطوار ما بعد الربكة، بعد أسرة واحدة في معدلات البقاء والمعدلات النمو الوراثي ونسبة التحول الغذائي والانتاجية مقابلة بالمجموعة المتماثلة في الحجم من الأطوار ما بعد الربكة. وعلى إستدال فترة التجربة لم تسجل فروقات ملموسة (P<0.05) في تركيز كل من الرقم الهيدروجيني، الأمونيا NH3، النترات NO3 وفي عينات المياه الداخلة والخارجة في أحوال الربيان. وفي ذلك ما يشير ضبطاً إلى عدم عمل المرشح الحيوي بشكل صحيح. كما لم يحدث وأن تعرضت كلا التجربتين لأية أصابات مرتبطة طوال فترة التجربة، وبذلك فقد يكون نظام التربة المغلق بإعادة التدوير خياراً بديلاً لمنع المرض.

Assessment of Indian White Shrimp Fenneropenaeus indicus Culture in the Recirculating Aquaculture System

Assessment of F. indicus in RAS
Assessment of Indian White Shrimp *Fenneropenaeus indicus* Culture in the Recirculating Aquaculture System

Prepared by: _

Introduction
The Indian white shrimp *Fenneropenaeus indicus* had been cultured in the Jeddah Fisheries Research Center, JFRC, more than two decades. The JFRC conducted the R & D and selected this species as the most suitable one for rearing in the local hypersaline water among *Penaeus japonicus*, *P. monodon*, *P. semisulcatus* and *F. indicus*. The characteristics of *F. indicus* were growing well and easily maturing in the pond; so that the shrimp aquaculture rapidly developed in the Kingdom. Due to the strike of White Spot Syndrome, WSS, the shrimp production dramatically decreased in 2010. To recovery and develop the shrimp industry, the Ministry and private companies aimed at biosecurity to prevent the pathogen introduction including the Specific Pathogen Free (SPF) shrimp seed, biofloc system and low density for broodstock maintenance. The SPF shrimp was introduced in 2014 and the shrimp production is improving in the Kingdom. The JFRC attempted to use the Recirculation Aquaculture System (RAS) as the alternative method for shrimp culture.

Abstrate
The JFRC operated the *F. indicus* culture to detect the possibility by using the Recirculation Aquaculture System. Two experiments were carried out from June to December 2016. The first experiment evaluated the growth of shrimp by switching the feed from starter-3 feed to grower-I feed when PL 117. Although these two sizes of feed consisted of the same formula, the group receiving starter-3 feed obtain better SR, final abw, SGR, FeR and productivity than the group receiving grower-I feed from PL 117 to PL 216. The shortage of some nutrient in the grower-I feed might the main reason. The second experiment evaluated the growth of shrimp by stocking with uneven sized PL and even sized PL. The results indicated that the group stocking with even sized PL obtained better SR, SGR, FCR and productivity than the group stocking with uneven sized PL. During the experimental period, there was no significant difference (P < 0.05) for the concentration of pH, NH3, NO2-, NO3- between water inlet and outlet of shrimp tank. It implied the bio-filter didn't work properly. During the cultural period, we didn't find the breaking out of pathogen; the RAS might an alternative option to prevent disease.

Materials and Methods
Two experiments were carried in the JFRC RAS unit from June 20 to December 21, 2016. The parameter of water quality was weekly collected by the Jeddah Fish Health & Safety Laboratory, JFHSC. The data were analyzed by the one-way ANOVA and Duncan's Multiple Range Test (2 tails, a = 0.05). The daily feeding schedule was performed by automatic feeding machine and the timing was set within 02:00-24:00H. It meant feeding frequency was 23 times a day. Every feeding amount was equal. The daily feeding amount was adjusted at 09:00 depending on whether the residual feed existed from previous day or not. The feeds were from NAQUA Company and shown in the Table 1. Average body weight was collected every 4 weeks.
Table 1. Specification of NAQUA’s shrimp feed Starter-3 and Grower-I.

<table>
<thead>
<tr>
<th>Feed</th>
<th>Moisture</th>
<th>Crude protein</th>
<th>Crude fat</th>
<th>Ash</th>
<th>Fiber</th>
<th>Form</th>
<th>Size</th>
<th>Suitable shrimp size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starter-3</td>
<td>11% max</td>
<td>40% min</td>
<td>7% min</td>
<td>15%</td>
<td>4% max</td>
<td>Crumble</td>
<td>1.4-2.5 mm</td>
<td>3-5g</td>
</tr>
<tr>
<td>Premium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grower-1</td>
<td>11% max</td>
<td>40% min</td>
<td>7% min</td>
<td>15%</td>
<td>4% max</td>
<td>Pellet</td>
<td>ϕ2.2mm</td>
<td>5-15g</td>
</tr>
<tr>
<td>Premium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>L: 3-4mm</td>
<td></td>
</tr>
</tbody>
</table>

**Experiment 1:**
This experiment was designed to detect the effects of feeding with starter-3/grower-1 feed on the growth of F. indicus in the RAS. Four units of 10-M3-FRP round tanks were stocked with 1,740 shrimp each; the stocking density was 174 shrimp/M². Due to the uniform PL were unavailable, two-sized PL were mixed to match the enough number for experiment. The mean age of uneven sized post larvae was PL 32. Each treatment had 2 replicates. The first treatment received starter-3 feed throughout whole cultural period. The 2nd treatment received starter-3 feed for first 85 days (PL 32-116, phase 1) and then switched to grower-1 feed for the rest 99 days (PL 117-216, phase 2). These two treatments were listed below:

Table 2. The stocking density and feed source of each treatment.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Tank no.</th>
<th>Stocking density (shrimp/M²)</th>
<th>Phase 1</th>
<th>Phase 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uneven PL, starter-3</td>
<td>3 &amp; 6</td>
<td>174</td>
<td>Starter-3</td>
<td>Starter-3</td>
</tr>
<tr>
<td>(UPL-S3)</td>
<td></td>
<td></td>
<td>(PL 32-116)</td>
<td>(PL 117-184)</td>
</tr>
<tr>
<td>Uneven PL, starter-3 +</td>
<td>7 &amp; 8</td>
<td>174</td>
<td>Starter-3</td>
<td>Grower-1</td>
</tr>
<tr>
<td>Grower-1</td>
<td></td>
<td></td>
<td>(PL 32-116)</td>
<td>(PL 117-184)</td>
</tr>
<tr>
<td>(UPL-SG)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

When the shrimp grew to PL 117, the data of average body weight (abw) and specific growth rate (SGR) were analyzed by t-test. Furthermore, the survival rate (SR), abw, SGR, feed conversion rate (FRC) and productivity were analyzed too, when the experiment was terminated.

**Experiment 2:**
This experiment was designed to detect the effects of stocking with even/uneven sized post larva on the growth of F. indicus in the RAS. Treatment 1 had two replicates and each replicate was stocked with 1740 shrimp in 10-M3-FRP round tanks. The shrimp of treatment 1 were uneven age and the mean age was PL 32. For the treatment 2, three units of 10-M3-FRP round tanks were stocked with 1740 shrimp with even sized PL 18. All the shrimp were
fed with starter-3 feed throughout the whole experiment. The details of two treatments were listed below:

Table 3. The stocking density and feed source of each treatment.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Tank no.</th>
<th>Stocking density (shrimp/M²)</th>
<th>Feed source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uneven PL, starter-3 (UPL-S3)</td>
<td>3 &amp; 6</td>
<td>174</td>
<td>Starter-3</td>
</tr>
<tr>
<td>Even PL, Starter-3 (EPL-S3)</td>
<td>1, 2 &amp; 4</td>
<td>174</td>
<td>Starter-3</td>
</tr>
</tbody>
</table>

Results and Discussions
During the experimental period, 10% of new water was daily added to the system.

Experiment 1:
The results of shrimp culture after 184 days were shown in Table 4.

<table>
<thead>
<tr>
<th>Group</th>
<th>Tank</th>
<th>Shrimp no.</th>
<th>SR (%)</th>
<th>Abw (g)</th>
<th>SGR (%/day)</th>
<th>Final biomass (Kg)</th>
<th>FCR</th>
<th>Productivity (Kg/M²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>initial</td>
<td>Final</td>
<td>initial</td>
<td>Final</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UPL-S3</td>
<td>3</td>
<td>1726</td>
<td>852</td>
<td>49.36</td>
<td>0.248</td>
<td>15.02</td>
<td>2.23</td>
<td>12.798</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>1738</td>
<td>892</td>
<td>51.32</td>
<td>0.248</td>
<td>16.14</td>
<td>2.27</td>
<td>14.4</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>1732</td>
<td>872</td>
<td>50.35</td>
<td>0.248</td>
<td>15.58</td>
<td>2.25</td>
<td>13.599</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>8</td>
<td>28</td>
<td>1.39</td>
<td>0</td>
<td>0.79</td>
<td>0.03</td>
<td>1.133</td>
</tr>
<tr>
<td>UPL-SG</td>
<td>7</td>
<td>1738</td>
<td>664</td>
<td>38.20</td>
<td>0.248</td>
<td>14.06</td>
<td>2.19</td>
<td>9.335</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>1738</td>
<td>722</td>
<td>41.54</td>
<td>0.248</td>
<td>13.85</td>
<td>2.19</td>
<td>10.002</td>
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<tr>
<td></td>
<td>Mean</td>
<td>1738</td>
<td>693</td>
<td>39.87</td>
<td>0.248</td>
<td>13.96</td>
<td>2.19</td>
<td>9.6685</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0</td>
<td>41</td>
<td>2.36</td>
<td>0</td>
<td>0.15</td>
<td>0.00</td>
<td>0.472</td>
</tr>
</tbody>
</table>

Means with different superscript within a column are significantly different (P < 0.05).

The shrimp received only starter-3 feed (UPL-S3 group) obtained better SR, final abw, SGR and productivity than those shrimp were switched to grower-l feed (UPL-SG). There were significantly different (P < 0.05) for the mentioned detected factors between two groups. To know the effects of different feed on the shrimp growth, the data were divided into two phases for further analysis. Since the feed was switched to grower-l for tank #7 & 8 (UPL-SG) at age of PL 117, the more details of abw and SGR were detected and analyzed. The results were shown in the Table 5.
Table 5. Comparisons of average body weight and specific growth rate between shrimp either received grower-l feed or not during different cultural phase.

<table>
<thead>
<tr>
<th>Group</th>
<th>Abw (g)</th>
<th>SGR (%/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPL-S3</td>
<td>0.248 ± 0a</td>
<td>8.00 ± 0.62a</td>
</tr>
<tr>
<td></td>
<td>(7.56-8.43)</td>
<td>(15.02-16.14)</td>
</tr>
<tr>
<td>UPL-SG</td>
<td>0.248 ± 0a</td>
<td>7.00 ± 0.04a</td>
</tr>
<tr>
<td></td>
<td>(6.97-7.03)</td>
<td>(13.85-14.06)</td>
</tr>
</tbody>
</table>

Values are the means with standard deviations of two replicates. Values presented in the parentheses are the ranges. Means with different superscript within a column are significantly different (P < 0.05).

During the phase 1 (PL 32-116), the abw and SGR were 7.00±0.04g and 3.93±0.01 respectively for the UPL-SG group; while 8.00±0.62g abw and 4.09±0.02 SGR for the UPL-S3 group. There was no significantly different (P > 0.05).

In the phase 2 (PL 117-216), the abw of those shrimp received only starter-3 feed (UPL-S3) was 15.58±0.79g and the abw of shrimp received grower-l feed (UPL-SG) was 13.96±0.15g. There was significantly different (P < 0.05) between two groups. The SGR were 0.68±0.02 and 0.69±0.02 for group UPL-S3 and UPL-SG respectively. There was no significant difference (P > 0.05) between two groups. For the whole cultural period, the SGR of UPL-S3 group and UPL-SG group were 2.25±0.03 and 2.19±0 respectively; there was significantly different (P < 0.05) between two groups.

Although the level of nutrient contents were the same between two sizes of feed (See Table 1), the results were different. The shrimp lost feed appetite and serious cannibalism happened in the UPL-SG group after changing the feed. Finally the serious cannibalism resulted in low survival rate. It might be short of some nutrient element in the grower-l feed. The growth curves were shown in the Fig. 1.
Experiment 2
The shrimp of group UPL-S3 grew from 0.248g abw to 15.88g abw within 216 days; while the shrimp of EPL-S3 group grew from 0.62g abw to 15.87g abw within 175 days (Fig. 1.). Although the initial abw were significantly different (P < 0.05) the EPL-S3 group obtained the same final abw as UPL-S3 (P > 0.05). The survival rate of group UPL-S3 and EPL-S3 were 50.30% and 69.42% respectively; there were significantly different (P < 0.05). The specific growth rate (SGR) of group UPL-S3 and EPL-S3 were 2.25 %/day and 3.16% /day respectively; there were significantly different (P < 0.05). It meant that the even sized shrimp obtained the better SGR than the uneven sized shrimp did. There was a big gap of the FeR; it could be due to higher cannibalism in the UPL-S3 group. The details of cultural results were shown in the Table 6.
Table 6. Results of shrimp culture the RAS initially stocked with even sized post larva and uneven sized post larva.

<table>
<thead>
<tr>
<th>Group</th>
<th>Tank</th>
<th>Shrimp no.</th>
<th>Shrimp no.</th>
<th>SR (%)</th>
<th>SR (%)</th>
<th>Abw (g)</th>
<th>Abw (g)</th>
<th>SGR (%/day)</th>
<th>SGR (%/day)</th>
<th>Final biomass (Kg)</th>
<th>Final biomass (Kg)</th>
<th>FCR</th>
<th>FCR</th>
<th>Productivity (Kg/M²)</th>
<th>Productivity (Kg/M²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPL-S3</td>
<td>3</td>
<td>1726</td>
<td>852</td>
<td>49.36</td>
<td>0.248</td>
<td>15.02</td>
<td>2.23</td>
<td>12.798</td>
<td>5.61</td>
<td>1.28</td>
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</tr>
<tr>
<td></td>
<td>6</td>
<td>1738</td>
<td>892</td>
<td>51.32</td>
<td>0.248</td>
<td>16.14</td>
<td>2.27</td>
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</tr>
<tr>
<td>Mean</td>
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<td>1732</td>
<td>872</td>
<td>50.30²</td>
<td>0.248²</td>
<td>15.58²</td>
<td>2.25²</td>
<td>13.599</td>
<td>5.57²</td>
<td>1.36²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td>8</td>
<td>8</td>
<td>1.39</td>
<td>0</td>
<td>0.79</td>
<td>0.03</td>
<td>1.133</td>
<td>0.05</td>
<td>0.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EPL-S3</td>
<td>1</td>
<td>1741</td>
<td>1274</td>
<td>73.18</td>
<td>0.062</td>
<td>15.68</td>
<td>3.16</td>
<td>19.983</td>
<td>3.76</td>
<td>2.00</td>
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</tr>
<tr>
<td></td>
<td>2</td>
<td>1741</td>
<td>1237</td>
<td>71.05</td>
<td>0.062</td>
<td>15.53</td>
<td>3.16</td>
<td>19.212</td>
<td>4.23</td>
<td>1.92</td>
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</tr>
<tr>
<td>Mean</td>
<td></td>
<td>1741</td>
<td>1115</td>
<td>64.04</td>
<td>0.062</td>
<td>15.51</td>
<td>3.16</td>
<td>17.288</td>
<td>4.25</td>
<td>1.73</td>
<td></td>
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<tr>
<td>SD</td>
<td></td>
<td>0</td>
<td>83</td>
<td>4.78</td>
<td>0</td>
<td>0.09</td>
<td>0.00</td>
<td>1.39</td>
<td>0.28</td>
<td>0.14</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Means with different superscript within a column are significantly different (P < 0.05).

The cannibalism was rarely found in the EPL-S3 group comparing to the UPL-S3 group. The result demonstrated stocking with the uniform sized PL could prevent cannibalism.

Parameter of water quality
The parameters of water quality for whole period among new water shrimp tank inlet water and shrimp tank outlet were listed in the Table 7. The concentration of NH₃ and N0₂- in the system of inlet water and outlet water were significantly different to the ones from new water (P < 0.05). There was no significant difference between inlet and outlet water (P > 0.05); moreover the NH₃ value was much higher than the allowable level. These results demonstrated that the system didn't work properly.
Table 7. Results of water quality of the RAS during the cultural period.

<table>
<thead>
<tr>
<th>Factor</th>
<th>New water</th>
<th>Inlet water (of shrimp tanks)</th>
<th>Outlet water (of shrimp tanks)</th>
<th>Allowable level</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.09±0.20&lt;sup&gt;b&lt;/sup&gt; (6.86-7.45)</td>
<td>7.26±0.19&lt;sup&gt;a&lt;/sup&gt; (7.04-7.70)</td>
<td>7.34±0.18&lt;sup&gt;a&lt;/sup&gt; (7.08-7.70)</td>
<td>6.7-8.6</td>
</tr>
<tr>
<td>NH&lt;sub&gt;3&lt;/sub&gt; (ppm)</td>
<td>0.013±0.005&lt;sup&gt;b&lt;/sup&gt; (0.010-0.020)</td>
<td>0.054±0.032&lt;sup&gt;a&lt;/sup&gt; (0.010-0.020)</td>
<td>0.081±0.036&lt;sup&gt;a&lt;/sup&gt; (0.010-0.130)</td>
<td>0.013</td>
</tr>
<tr>
<td>NO&lt;sub&gt;2&lt;/sub&gt;&lt;sup&gt;-&lt;/sup&gt; (ppm)</td>
<td>0.008±0.007&lt;sup&gt;b&lt;/sup&gt; (0.004-0.026)</td>
<td>0.019±0.006&lt;sup&gt;a&lt;/sup&gt; (0.007-0.031)</td>
<td>0.023±0.007&lt;sup&gt;a&lt;/sup&gt; (0.006-0.034)</td>
<td>0.200</td>
</tr>
<tr>
<td>NO&lt;sub&gt;3&lt;/sub&gt;&lt;sup&gt;-&lt;/sup&gt; (ppm)</td>
<td>0.276±0.403&lt;sup&gt;a&lt;/sup&gt; (0.010-1.000)</td>
<td>0.417±0.713&lt;sup&gt;a&lt;/sup&gt; (0.050-2.800)</td>
<td>0.409±0.587&lt;sup&gt;a&lt;/sup&gt; (0.050-1.900)</td>
<td>3.00</td>
</tr>
<tr>
<td>WT (℃)</td>
<td>28.1±0.7 (26.7-29.3)</td>
<td>27.8±1.3 (25.9-29.9)</td>
<td>27.5±1.3 (25.7-29.7)</td>
<td>25.0-31.0</td>
</tr>
<tr>
<td>Salinity (ppt)</td>
<td>44.0±0.3 (43.6-44.4)</td>
<td>44.1±0.2 (43.8-44.5)</td>
<td>44.1±0.3 (43.5-44.5)</td>
<td>25.0-45.0</td>
</tr>
</tbody>
</table>

Values are the means with standard deviations. Values presented in the parentheses are the ranges. Means with different superscript within a row are significantly different (P < 0.05).

In fact, the bio-media in the present bio-filter tank got stuck and only part of media moving in the bio-filter tank, although we made much efforts to keep the media continually moving. Nitrification is formally a two-step process; in the first step ammonia (NH3) is oxidized to nitrite (NO2<sup>-</sup>) and in the second step nitrite is oxidized to nitrate (NO3<sup>-</sup>). The first step is performed by Nitrosomonas and the second step is performed by Nitrobacter. Both two steps need oxygen to complete. To get best efficiency of nitrification, always the bio-media should be in the moving condition. Under the moving condition, the Nitrosomonas and Nitrobacter will easily get oxygen to perform the nitrification. We doubt the present bio-media is designed for using in the freshwater or ordinary seawater RAS. When we use it in hypersaline water with greater 42 ppt salinity, the bio-media will float continually. Beside the problem of bio-media, some more malfunction of RAS facility might result in adverse outcomes. For example, problem of the exhaustion of UV tube lifespan, sensor of drum filter, chilling facility for the water and air are to be solved. Installation of oxygen making machine is also recommended.

Special notes

• Poor growth rate

This was the first trial of shrimp culture in the RAS of the JFRC. We compared the previous culture cases and made the growth curves together based on the age as the cultural duration (Fig. 2). Beside the current growth curves from the RAS, the Fig. 2 consisted of three curves from outdoor pond culture and one curve obtained from indoor culture. All curves of the outdoor pond culture obtained higher slope comparing to the ones from RAS and indoor one in spite of the stocking density. Two curves of the RAS culture were similar to
the indoor one. In short, the slope of indoor culture was lower than the outdoor pond culture. Probably, natural food was unavailable in RAS and indoor culture.

![Diagram](image)

**Fig. 2. Growth curves between outdoor and indoor culture including the RAS culture.**

The data of these cultural cases in Fig. 2 were summarized and listed in Table 8. There was a trend of outdoor culture getting better harvesting size, SR and FeR comparing to indoor culture including RAS culture. The natural foods could be the main reason.
Cannibalism

There were some notable situations i.e. losing of appetite for the feed, more shrimp with broken rostrum, antenna and scaphocerite and serious cannibalism in the Tank 7 and 8 where the shrimp received grower-I feed (See Fig. 1). It might due to shortage of some nutrient element in the grower-I feed. High density, uneven-sized shrimp, unbalanced-nutrition feed and parasite are some important factors causing more cannibalism. Especially the formulated feed doesn't match the perfect food; the shrimp still needs natural food anyhow. This stated problem didn't happen in the previous outdoor culture.

Table 8. Summary of cultural results obtained from previous outdoor/indoor culture and the latest RAS culture for the F. indicus.

<table>
<thead>
<tr>
<th>Case</th>
<th>Final abw (g)</th>
<th>Productivity (Kg/M²)</th>
<th>SR (%)</th>
<th>FCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pond culture, 30 ind./M²</td>
<td>23.27</td>
<td>0.52</td>
<td>77.00</td>
<td>2.79</td>
</tr>
<tr>
<td>Pond culture, 110 ind./M²</td>
<td>20.34</td>
<td>1.65</td>
<td>61.68</td>
<td>2.48</td>
</tr>
<tr>
<td>Pond culture, 120-130 ind./M²</td>
<td>19.80</td>
<td>1.64</td>
<td>68.49</td>
<td>2.83</td>
</tr>
<tr>
<td>Indoor culture, 50 ind./M²</td>
<td>13.60</td>
<td>0.36</td>
<td>52.81</td>
<td>---</td>
</tr>
<tr>
<td>RAS, EPL-S3, 174 ind/M²</td>
<td>15.57</td>
<td>1.88</td>
<td>69.42</td>
<td>4.08</td>
</tr>
<tr>
<td>RAS, UPL-S3 &amp; UPL-SG, 174 ind/M²</td>
<td>14.77</td>
<td>1.17</td>
<td>45.11</td>
<td>5.87</td>
</tr>
</tbody>
</table>
Fig. 3. Cannibalism resulted in broken rostrum, antenna and scaphocerite. Right: serious damage of appendages; Middle: recovering after each molting; Left: ordinary shrimp.

• Astaxathin
The shrimp growing in the RAS appeared short of pigment and pale in color. Especially the shrimp appeared white instead of red in color after cooking (Fig. 4). Normally, the astaxathin was produced by algae e.g. Pluvialis algae or yeast Phaffia rhodozyma. Through the food chain, the astaxathin accumulates in the crustaceans. There was no natural food in the indoor RAS system; therefore the shrimp didn’t get enough astaxathin and causing white color after cooking. The situation can be improved by adding astaxathin in the feed. The white-leg shrimp fed a diet supplemented with 40 mg astaxanthin j 100 g for 4 weeks could obtain coloration comparable to that of the shrimp sold in the market, which had been reared in outdoor ponds (Yu etc, 2003)
Fig. 4. The shrimp didn’t appear red color after cooking because of astaxathin shortage under indoor culture.

Conclusions
1. The group of shrimp received only starter-3 feed obtained better SRI final abw, SGR and productivity than the group had been shifted to grower-1 feed.

2. Stocking with even sized PL obtained better SRI SGR, FeR and productivity comparing to stocking with uneven sized PL.

3. Probably the less gravity of bio-media resulted in the bio-media floating and steady on the water surface instead of suspending in the water. Therefore, the nitrification was not fully stretch running.

4. Because the RAS/indoor culture system lacked for the natural foods, the shrimp encountered slower growth, more cannibalism and less asaxanthin.

5. We didn’t find any pathogen breaking out in this pilot trial; the RAS maybe contribute the prevention of disease. It is worth to do more investigation in this system.

6. To have more integrated and accurate information of shrimp culture in RAS, the malfunction of bio-media, UV tube, sensor of drum filter, chilling facility are to be eliminated. Also installation of oxygen making machine is recommended.