Vegetarian Shrimp: Pellet-free Shrimp Farming
Nicholas Romano and Vikas Kumar

Shrimp farming can be a highly lucrative business around the world, but has increasingly been characterized by intensification, with greater inputs of feed. Intensification has increased the risk of disease outbreaks and the proportion of operating costs represented by feeds can be as much as 60 percent. Various strategies have been investigated to address these issues, such as using functional feeds designed to improve the productivity and health of shrimp by additions of supplements. Moreover, researchers are continually evaluating appropriate replacements for more-expensive marine ingredients (Gatlin et al. 2007).

One of the potential constraints in shrimp feeds, however, is the requirement for expensive cholesterol and pigments. Additional supplements such as probiotics, prebiotics, extracts and organic acids to create functional feeds further increases feed cost. Consequently, the purchase of commercial aquafeeds may be out of reach for many small-scale farmers around the world.

Alternatively, farmers can make pellets on site with locally available ingredients and/or using trash fish (Gonzalez and Allan 2007). There are several drawbacks to this practice, such as inefficient use of feeds, leading to water quality deterioration, variable ingredient quality and the potential introduction of pathogens (Kim et al. 2007).

In this situation, a potentially better approach might be to combine the “Aquamimicry” concept that relies on the use of fermented rice bran (FRB) to stimulate natural zooplankton (Romano 2017) with the sole provision of fermented soybeans (FSY) as feed for shrimp. This combination that completely replaces the need to buy or create pellets is referred to as “Aquamimicry fermented soybeans” (AFSY). Despite being contrary to traditional farming practices, AFSY has been successful in the extensive and semi-intensive farming of black tiger shrimp and whiteleg shrimp in some parts of Thailand, Vietnam, Ecuador and India.

This brief article will describe the overall methodology of pellet-free farming by using AFSY as a potential means to improve the cost-effectiveness and sustainability of shrimp aquaculture. Application of AFSY does not require harsh chemicals or antibiotics because diseases are minimized and water quality improved. Efforts are underway to disseminate this knowledge to farmers throughout the world and to share their experiences, opinions and advice with others (Figs. 1 and 2).

Study Methods
This method relies on implementing the Aquamimicry concept within ponds by adding FRB to stimulate the natural production of zooplankton (particularly copepods) prior to stocking shrimp. To create FRB, rice bran is ground to a fine powder, added to water at a 1:1 ratio and then Bacillus probiotics or hydrolytic enzymes are added with aeration. After 24 hours, an initial application of the mixture is made to ponds at 50-100 ppm. Copepods will bloom within two weeks, depending on water source, temperature and previous pond management, but can be as early as two days. Periodic applications of probiotics to pond water and dragging a chain around the pond bottom should also be done. It is not necessary to have a split-pond design as required for Aquamimicry. More details on this protocol...
TABLE 1. INGREDIENTS AND QUANTITY TO CREATE FERMENTED SOYBEANS.

<table>
<thead>
<tr>
<th>INGREDIENTS</th>
<th>AMOUNT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean meal (defatted)</td>
<td>5 kg</td>
</tr>
<tr>
<td>Rice bran</td>
<td>2 kg</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>2 kg</td>
</tr>
<tr>
<td>Roasted soybeans</td>
<td>1 kg</td>
</tr>
<tr>
<td>Calcium carbonate</td>
<td>100 g</td>
</tr>
<tr>
<td>Fermented soy sauce</td>
<td>One tablespoon</td>
</tr>
<tr>
<td>Probiotic *</td>
<td>1 g</td>
</tr>
<tr>
<td>Egg</td>
<td>1</td>
</tr>
<tr>
<td>Water</td>
<td>20 L</td>
</tr>
</tbody>
</table>

* The probiotic can be Bacillus sp. or their hydrolytic enzymes.

TABLE 2. RECOMMENDED FEEDING RATES OF FERMENTED SOYBEANS TO SHRIMP. THE DAILY TOTAL QUANTITY SHOULD BE DIVIDED INTO THREE TO FOUR PORTIONS.

<table>
<thead>
<tr>
<th>SHRIMP SIZE (g)</th>
<th>FEEDING RATE (PERCENT BODY WEIGHT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – 5</td>
<td>5 – 4</td>
</tr>
<tr>
<td>5 – 10</td>
<td>4 – 3</td>
</tr>
<tr>
<td>10 – 20</td>
<td>3 – 2</td>
</tr>
<tr>
<td>20 – 30</td>
<td>2 – 1</td>
</tr>
</tbody>
</table>

can be found at Romano (2017) and at www.bioshrimp.com.

After the copepod bloom, early post-larvae are stocked at 20/m², a density that is substantially lower than intensive farms. The exact stocking density depends on pond size, growth rates, water quality and market demand. After stocking, FRB is added daily at 1 ppm throughout the culture cycle to serve two important functions. First, this will create some biofloc to help maintain water quality, but at a much lower scale (< 25 mL/L as measured by an Imhoff cone) than an established biofloc-based system. Second, FRB will support pond zooplankton and act to provide supplemental nutrition to the shrimp. In addition to the post-larvae directly feeding on live feeds, it is believed that the larger and more benthic shrimp consume copepod eggs when they sink to the pond bottom. Once shrimp reach 40-50 g (around 180 days of culture), the crop should be partially harvested to ensure that stocking densities do not become excessive.

To create FSY, soybean meal crumble is fermented with additional ingredients in smaller amounts. An example of this formulation is shown in Table 1 and can be done in simple containers (Fig. 3) or in cement mixers. Other farms use variations of this formulation, based on experience and availability of ingredients. For example, fermented soy sauce can substitute for salt and wheat bran can substitute for rice bran. When applying this mixture to ponds, feeding trays should be used to gauge and adjust feeding rates. Table 2 shows a general feeding schedule, but as a rule, underfeeding is preferred to overfeeding to minimize the negative effects of excess FSY decomposing in the pond.

REASONS FOR SUCCESS

Based on reports from farmers applying this management system, shrimp growth reportedly can be up to 0.5 g/d and survival over 80 percent with no serious disease outbreaks. There are several contributors to the success of this protocol, including improvement in water quality, production of live feeds that are consumed by shrimp and the pretreatment of SBM to improve its nutritional value and palatability.

Copepods are a natural food source of shrimp, containing astaxanthin, amino acids and fatty acids, such as omega-3 fatty acids, that are not found in terrestrial plant-based ingredients, such as soybean meal. Therefore, the consumption of live foods by shrimp is essential, inasmuch as soybean meal is nutritionally inferior to fishmeal in the diets of crustaceans (Taher et al. 2017). In addition to deficiencies in certain nutrients, plant proteins often contain high amounts of antinutritional factors, including phytic acid, non-starch polysaccharides, protease inhibitors and tannins that disrupt nutrient utilization and can impart a bitter taste to the shrimp.

It has yet to be determined whether pretreatment reduces antinutritional factors and/or improves the nutritive value of soybean meal. Some species of Bacillus can produce amino acids, lipids or pigments from the degradation of plant proteins (Eaksuree et al. 2016) and reduce some antinutritional factors (Yuan et al. 2017). Shrimp with full intestines have been routinely observed to actively seek out and consume FSY (Fig. 4) and some farmers even insist that shrimp prefer FSY over commercial pellets. To better understand this and potentially optimize the pretreatment method,
research should explore changes to the nutritional value of FSY during fermentation, such as measuring the amino acid and starch composition and any bioactive compounds.

PERSPECTIVES
This protocol can be particularly attractive for new or resource-poor farmers not able to invest in expensive aquafeeds. The key to success of AFSY, however, is the pretreatment method of the soybean meal and rice bran. There are commercially available products designed for pellet-free shrimp farming, based on various enzymes produced from probiotics to degrade less digestible nutrients and/or antinutritional factors. As this protocol is still new and evolving, simple pilot studies should be tried before application to commercial-scale ponds. This can include pretreating the soybean meal and observing shrimp behavior under controlled conditions to ensure that shrimp will actually consume the FSY. If the shrimp do not immediately feed, then the formulation, product and/or duration of pretreatment can be adjusted accordingly. As a first criterion, the FSY should have the smell of baker’s yeast, without any signs of rancidity or ammonia.

Shrimp produced using AFSY are redder in color when cooked, likely from the consumption of natural foods that contain pigments. This would be beneficial in terms of marketing, while the consumption of zooplankton would also likely to increase healthier fatty acids for human consumers. Commercial production is already underway in some parts of Thailand, Vietnam, Ecuador and India (Fig. 5). There is also a push to market shrimp produced by AFSY as organic. However, such a distinction is prevented because most commercially available soybeans are genetically modified organisms. Although other protein sources should also be investigated, AFSY-produced shrimp could be advertised as “sustainably farmed” to appeal to more conscientious buyers. In addition, it would be particularly helpful for governments to encourage farmers to adopt AFSY, such as providing incentives and promoting these products to consumers.

CONCLUSION
The creation of marine-based products from only the input of pretreated plant sources is a remarkable technology, with farmers from around the world attesting to the success of this protocol. By farmers sharing their experiences and advice via social media and at workshops and conferences, procedural modifications can be anticipated over time. Researchers can also play an active role to further optimize this protocol. The application of AFSY only may not be applicable to all farmers, particularly those operating intensive systems, but it may have some potential to be integrated as a supplement to commercial pellets. Even a partial adoption of AFSY can reduce feeding costs and improve the sustainability of shrimp farming.

Notes
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This article is based on attendance of the first author at an “Aquamimicry” international workshop in Thailand during 9-13 January 2017. The event was organized by the Aquamimicry Aquaculture Alliance and participants included farmers from around the world. Program managers were Veerasun Prayotamornkul, Jimmy Lim, Cen Cho and David Kawahigashi. For more technical details regarding the amounts and types of probiotics, please visit www.bioshrimp.com.

References


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