水研センター研報，第40号，83－88，平成27年
Bull. Fish. Res. Agen. No. 40, 83－88, 2015

Good Aquaculture Practices to Reduce the Use of Chemotherapeutic Agents, Minimize Bacterial Resistance, and Control Product Quality

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Abstract: A significant challenge to the expansion of aquaculture production is controlling the outbreak of disease. Many farmers who experience the potential loss of stock from disease may choose to use chemotherapeutic agents to minimize their loss. It is generally understood that a disease in aquaculture is a combination of the health of the animal, the condition of the environment and the presence of a pathogen. From this concept there are a number of precautionary measures that farmers may practice to minimize disease outbreaks. The principles of Hazard Analysis Critical Control Point (HACCP) may be useful risk management tools to reduce pathogens, animal stress and the need for chemotherapeutic agents to control disease outbreaks on the farm.

Key Words: good aquaculture practices, chemotherapeutic agents, bacterial resistance, food safety

Introduction

As the global demand for seafood increases, the trend towards high density aquaculture systems grows. These systems referred to as "intensive aquaculture" increasingly rely on inputs of oxygen, formulated feed, and the application of agrochemicals, and antibiotics. This method of culture may also create stressful conditions for the animals and increase the risk of bacterial infections and therefore the use of chemotherapeutic agents (Sapkota *et al*., 2008).

Shrimp is the single most popular type of seafood in the United States and over 90 percent of shrimp products are farm raised and imported primarily from Southeast Asian countries. The primary hazards associated with aquaculture shrimp are contamination from pathogens and residues from unapproved drugs. The origins for these hazards are from production farms and can remain in or on the product throughout the normal cleaning, rinsing and packaging process.

Between 2001 and 2003 the U.S. Food and Drug Administration analyzed 1,234 samples from 103 shrimp aquaculture farms representing six countries for fecal coliforms, *Escherichia coli*, and *Salmonella*. A significant relationship was found between the log number of fecal bacteria and the probability that any given sample would contain *Salmonella*. The study concluded the occurrence of *Salmonella* bacteria in shrimp from aquaculture farms is directly related to the concentration of fecal bacteria in the source and production pond water (Koonse *et al*., 2005).

Fig. 1.

The importance of chemical and antimicrobial compounds in the protection of animals has been acknowledged, but the negative impact and use of these agents in animals raised for food is a concern.

2015年1月30日受理（Received on January 30, 2015）
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The detection of certain banned chemotherapeutic agents in fish and crustaceans in international trade during 2001-2002 led to greater attention about the potential health risks from farm raised seafood products (Iddya, 2012).

Good Aquaculture Practices

Good aquaculture practices (GAqP) can be defined in many ways. In general it is based on preventive practices that are developed and implemented to meet the needs of the species, culture methods and local environmental conditions. When aquaculture producers take time to identify potential risks to their operation and implement controls to manage the risk, then the potential for disease and the use of chemotherapeutic agents is minimized.

The Hazard Analysis Critical Control Point (HACCP) principles can be used as a preventive risk management system to control the introduction of pathogens at aquaculture facilities. The HACCP approach is based on prevention and requires a hazard analysis that identifies a potential hazard in the system and then a Critical Limit, with a maximum and or minimum point, is set for each component of the system. When monitoring the aquaculture system and a critical limit has been in violation, then a corrective action is taken to bring the system back into compliance (Jahncke *et al.*, 2002).

These HACCP principles provide a step by step approach to identify and control hazards found in the environment and production process for both freshwater and marine aquaculture. The following are the seven basic principles with an example:

Fig. 2.

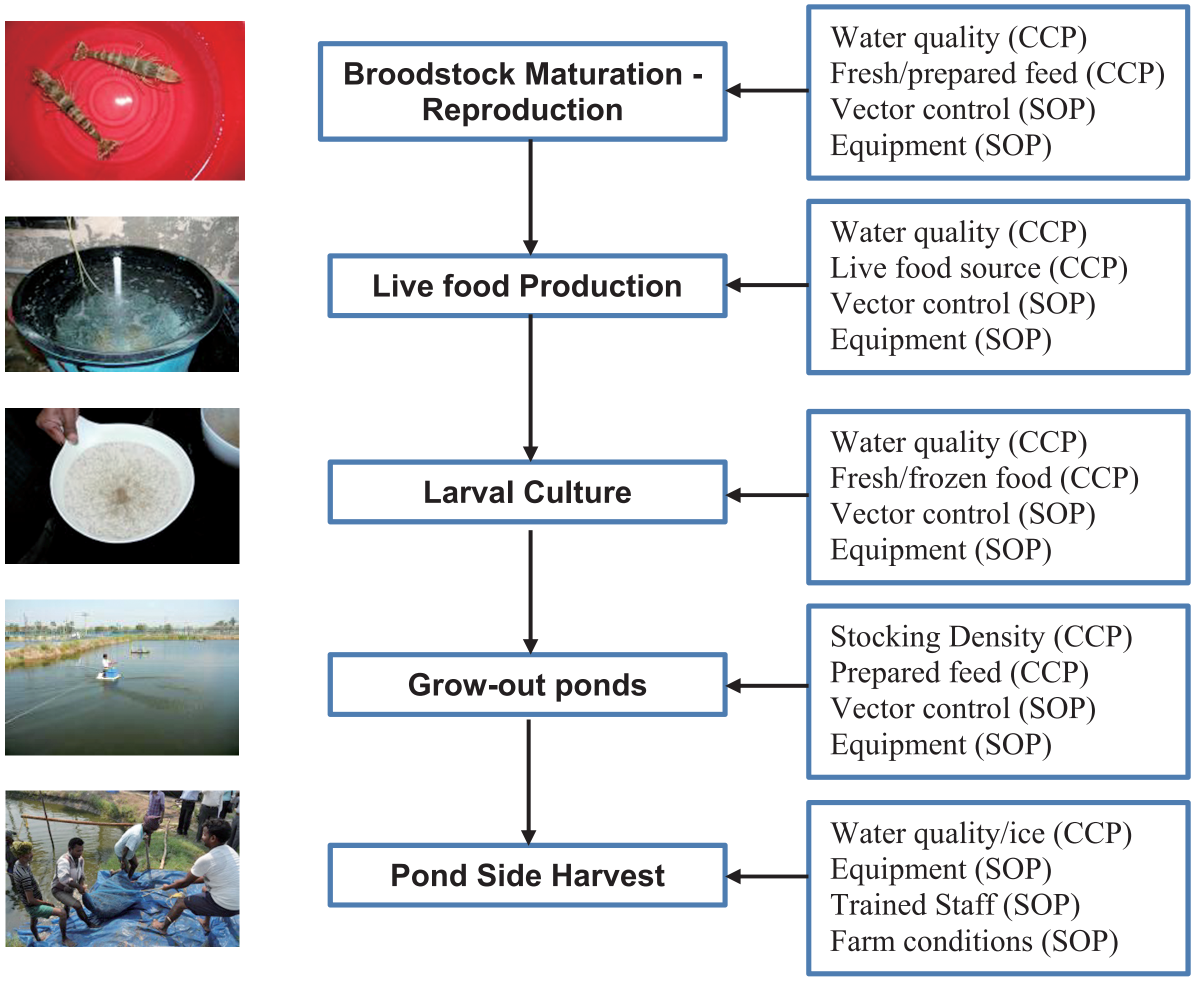
1. Hazard and Risk Analysis: Collect and evaluate information on hazards associated with the product under consideration to decide the likelihood of the occurrence and the severity of the occurrence. To help identify a potential hazard a farmer should construct a flow diagram with all of the inputs to the farm and then evaluate a control for each potential hazard.
   - See Fig. 3 for a shrimp farm flow diagram.

2. Identify Critical Control Point (CCP): This step is essential to prevent or eliminate a hazard or reduce it to an acceptable level.
   - For example a shrimp farmer may choose critical water quality parameters such as minimum and maximum oxygen and temperature levels.

3. Establish Critical Limits: A maximum and/or minimum value to which a physical, chemical or biological hazard must be controlled to prevent, eliminate or reduce to an acceptable level the occurrence of a hazard.
   - For example a critical limit could be stocking density at a hatchery tank and the ratio of live feed to animal.

4. Establish Monitoring Procedures: Monitoring is a process that the aquaculture operation relies on to maintain control of a Critical Control Point. Accurate monitoring is important to help determine when a CCP has deviated from the desired range. Failure to properly use and monitor chemotherapeutic agents may result in detectable residues in the tissue of aquacultured products.
   - For example, monitoring a specific water quality parameter every day or more frequently depending on the production system.

5. Establish Corrective Actions: The farmer should identify procedures to follow when a deviation from the acceptable range occurs.



CCP – Critical Control Point
SOP – Standard Operating Procedure

Fig. 3. Process flow diagram of an integrated shrimp farm with hatchery.

The farmer will implement a corrective action plan after the deviation has been identified and prepare a long term solution as soon as possible.

- For example if a farmer has identified the feed supply for the hatchery does not conform to required standard, the product is rejected and the farmer contacts an alternate feed supplier for new feed.

6. Establish Verification Procedures: This procedure helps to determine the validity of the operation and verify that the farm is operating according to plan.
   - For example the farmer may review daily water quality parameter sand feeding records to determine if the production system is meeting expected output.

7. Establish Record Keeping Procedures: The final step is to document all previous steps, from the Evaluation of Hazards and flow diagram, the identification of Critical Control Points and Critical Limits, and any Corrective Actions taken, and all Verification Procedures.
   - Records should be made for all identified Critical Control Points and be accessible to staff in paper or electronic format.

Fig. 3 is an example of an operational flow diagram for an integrated shrimp farm with brood stock, hatchery, nursery, and growout production.

Preventive Measures

A standard operating procedure (SOP) manual is an important document the farmer should assemble. This should include facility design and flow diagram, general husbandry procedures for each step in the production process, restricted access areas, waste management, pest control and staff rules. Good Aquaculture Practices may also include welfare of the animals, environmental integrity and social responsibility.

There are a number of biological, chemical and physical precautionary measures that can be undertaken. The following are examples of how to apply these practices on the farm.

Biological: Includes measures to prevent or treat infections such as the proper use of chemotherapeutic agents or the use of vaccinesas well as management practices to prevent the spread of pathogens by isolating and testing incoming seed stock. In addition, providing clean water and sanitary facilities for staff and proper farm security help to control the spread of pathogens from humans and animals.

Chemical: Includes measures that are used to prevent the introduction of pathogens or vectors by treating materials before they enter the facility. For example, chlorination or ozone can be used to treat incoming water, and iodine and chlorine can be used to treat other potential vectors such as tools, footwear and clothing.

Physical: Includes barriers that may be useful to prevent vectors from contaminating a farm site. Physical barriers can be stress reducing practices like proper stocking densities, optimal levels for dissolved oxygen and temperatures, and proper feeding practices.

Table 1. The following hazard analysis for an intensive marine shrimp farm.

Identify Potential Hazard	**Is the Hazard Significant**	**Justification**	**Preventive Measures**	**CCP**
Seed stock	Yes	Shrimp larvae may contain detectable pathogen	SPF certification for each receipt. Quarantine procedures and test periodically (CCP)	Yes
Water Source	Yes	Potential pathogens	Provide pre-treatment to ensure water supply is safe (CCP)	Yes
Feed Source	Yes	May result in and poor production	Certificate from feed supplier to ensure standard (CCP)	Yes
Stocking Density	Yes	Important to optimize production	Controlled by Standard Operating Procedure (SOP)	Yes and No
Effluent or Recirculated Water	Yes	Effluent may contain pathogens	Controlled by Standard Operating Procedure (SOP)	Yes and No
Animal and Human Vectors	Yes	May transfer contaminants and pathogens	Controlled by Standard Operating Procedure (SOP)	No
Farm Equipment and Sanitation	Yes	Equipment may become contaminated with pathogens	Controlled by Standard Operating Procedure (SOP)	No

SPF – Specific Pathogen Free
CCP – Critical Control Point
SOP – Standard Operating Procedure

Conclusion

Good Aquaculture Practices may be applied to many different kinds of aquaculture systems in a variety of management strategies. The key elements can be summarized as reliable sources of stock, good diagnostic and detection methods for disease, disinfection and eradication of pathogens and best management practices. HACCP principles provide a logical step by step approach to help prevent pathogen contamination and the outbreak of disease on the farm site. This management approach allows the farmer to choose the most important process control steps and then choose appropriate critical control points and control measures to minimize risk to the animals and the farm operation and insure that chemotherapeutic agents if needed will be used wisely.

References

Jahncke M. L., Browdy C. L., Schwarz M. H., Silva J. L., Smith D. C., and Stokes A. D., 2002: Risk management, disease prevention, and HACCP principles: Application of hazard analysis critical control point (HACCP) principles as a risk management tool to control viral pathogens at shrimp aquaculture facilities. NOAA Office of Sea Grant, Virginia Graduate Marine Science Consortium and the Virginia Sea Grant College Program, Publication VSG-02-10, Pages 1-33.

Karunasagar I., 2012: Public health and trade impact of antimicrobial use in aquaculture, in "Improving biosecurity through prudent and responsible use of veterinary medicines in aquatic food production" (ed by Bondad-Reantaso M. G., Arthur J. R. and Subasinghe R.P.) FAO Fisheries and Aquaculture Technical Paper No. **547**. Rome, FAO, pp. 1-9.

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Jahncke M. L., Browdy C. L., Schwarz M. H., Segars A., Silva J. L., Smith D. C., Stokes A. D., 2002: Risk management, disease prevention, and HACCP principles: Application of hazard analysis critical control point (HACCP) principles as a risk management tool to control viral pathogens at shrimp aquaculture facilities. NOAA Office of Sea Grant, Virginia Graduate Marine Science Consortium and the Virginia Sea Grant College Program, Publication VSG-02-10, Pages 1-33.

The authors identify how the principles of HACCP (Hazard Analysis Critical Control Point) can be used as a preventive risk management system to control the introduction of pathogens and the outbreak of disease in shrimp aquaculture facilities. The HACCP approach requires a hazard analysis that identifies a potential hazard in the system and then a Critical Limit with a maximum and or minimum point is set for each component of the system. When monitoring the aquaculture system and a critical limit has been in violation, then a corrective action is taken to bring the system back into compliance.

To develop an effective biosecurity program fish and shrimp farmers should follow these principles based on seafood HACCP: 1) Perform Systematic Hazard Analysis, 2) Determine Critical Control Points, 3) Establish Critical Limits, 4) Determine Appropriate Corrective Actions, 5) Establish Monitoring Procedures, 6) Establish Verification Procedures, 7) Establish Record Keeping Systems.

Karunasagar I., 2012: Public health and trade impact of antimicrobial use in aquaculture, in "Improving biosecurity through prudent and responsible use of veterinary medicines in aquatic food production" (ed by Bondad-Reantaso, M.G., Arthur J. R. and Subasinghe R.P.) FAO Fisheries and Aquaculture Technical Paper No. **547**. Rome, FAO,pp. 1-9.

The Food and Agriculture Organization of the United Nations (FAO), the World Health

Organization (WHO) and the World Organization for Animal Health (OIE) organized consultations and technical meetings to review the global seafood trade and the use of antimicrobial agents in aquaculture and develop recommendations. The author outlines how detection of certain banned antibiotics in fish and crustaceans in international trade during 2001-2002 lead to greater attention on the public health risks owing to the use of antimicrobial agents in aquaculture. Most fish importing countries adopt a zero tolerance approach regarding residues of antimicrobials that are banned for use in food animals. In such cases, residue levels that attract regulatory action are based on analytical capability rather than toxicology of the residues.

Koonse B., Burkhardt W., Chirtel S., and Hoskins G., 2005: Food safety and aquaculture, controlling risk, coliform bacteria: Salmonella and Sanitary Quality of Aquaculture Shrimp. *J. Food Prot.*, **68**, No 12, 2527-2532.

The authors examined the prevalence of *Salmonella* and coliform bacteria on shrimp aquaculture farms in several Asian countries to develop guidelines or preventative measures for reducing *Salmonella* and fecal contamination on products harvested from these farms. A significant relationship was found between the log number of fecal bacteria and the probability that any given sample would contain *Salmonella*. The likelihood of finding *Salmonella* in grow-out pond water increased 2.7 times with each log unit increase in fecal coliform concentration and 3.0 times with each log unit increase in *E. coli* concentration. *Salmonella* is not part of the natural flora of the shrimp culture environment nor is it inherently present in shrimp grow-out ponds. The occurrence of *Salmonella* bacteria in shrimp from aquaculture operations is related to the concentration of fecal bacteria in the source and grow-out pond water.

Sapkota A., Sapkota A., Kucharski M., Burke J., McKenszie S., Walker P., Lawrence R., 2008: Aquaculture practices and potential health risks: Current knowledge and future priorities. *Environ. Int. J.*, **34**, 1215-1226.

The authors conducted an extensive literature search with 145 peer reviewed papers to identify current global aquaculture practices and the potential health risks from aquacultured seafood. The authors focused on aquaculture production in Asia as having 11 of the top 15 producing countries in the world. The paper identifies chemical and biological contaminants used by the aquaculture industry and the potential impacts on food safety and human health. Tables identify the top 15 countries that use antibiotics and the prevalence of antibiotic resistance in the environment as a potential health concern. As global aquaculture production continues to increase worldwide with an emphasis on intensive systems, exposure to various hazardous chemical and biological compounds is a concern. The authors conclude the increased use of chemotherapeutic agents is contributing to elevated levels of antibiotic residues and antibiotic resistant bacteria.