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An implementation of the hazard analysis and critical control points (HACCP) system in the cage culture of *Siniperca scherzei* in Zhelin Lake, China

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The quality and safety of aquatic products has always been the first priority in food quality control in China. The Hazard Analysis and Critical Control Points (HACCP) is recognized as an effective system designed to improve food safety. To promote the establishment and implementation of the HACCP system in the aquaculture industry in China, the paper analyzed potential hazards in the cage aquaculture of *Siniperca scherzei* and defined the critical control point. Meanwhile, the table of HACCP plan was established.

Key words: Hazard analysis and critical control points (HACCP), cage culture, *Siniperca scherzei*, quality.

INTRODUCTION

The Hazard Analysis and Critical Control Points (HACCP) system was introduced in the 1960s by NASA for the design and manufacture of food for space flights (Mayes, 1998; Panisello and Quantick, 2001; Song and Wu, 2002; Mul and Koenraadt, 2009). Subsequently, HACCP has been recognised internationally as a logical tool for the adaptation of traditional inspection methods to a modern, science-based, food safety system (Mayes, 1993; Maldonado et al., 2005; Sun and Ockerman, 2005). The application of HACCP in aquaculture aims to ensure the comprehensive monitoring and management of factors relevant to the operation of an aquaculture facility. These factors can include the environment surrounding the culture site, the water quality, the water body used for the culture, and the feedstuff and pesticide used throughout the whole production cycle.

Zhelin Lake (308 km^2) is located on the upper reaches of the Xiu River in Jiangxi Province of China. It occupies the three counties of Yongxiu, Wuning, and Xiushui. The cage culture site investigated in this research is located along the upstream reaches of Zhelin Lake. This site is an environmentally friendly aquaculture system in Jiangxi province. *Siniperca scherzei* is the most popular of the various species (*S. scherzei, Lateolabrax japonicus, Silurus meridionalis*) that are raised there in more than 260 cages. *S. scherzeri* is considered to be valuable freshwater species that are widely cultured in China.

This paper further elaborates on the identification of the

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risk factors and critical control points (CCPs) for the cage culture of *S. scherzei* in Zhelin Lake and presents suggestions for corrective actions. We have developed a checklist based on this information and on evaluative inputs by the manager of the cage culture site that can be used to control hazards that have a potential impact on the cage culture of *S. scherzei*, so as to promote the establishment and implementation of the HACCP system in the aquaculture industry in China.

HACCP STEPS

Based on the seven principles of the HACCP system, the following steps or principles provide a HACCP model for the cage culture of *S. scherzei*.

Hazard analysis

Design and construction of the base

Faulty design and construction of cages may present chemical and biological hazards at the *S. scherzei* culture site. These factors can degrade water quality by obstructing water exchange, and they can readily induce disease. Once disease has appeared, it can easily progress to an outbreak and cause great economic losses. According to the governing ordinance, the cages are of the net structure type. They are constructed of polyethylene. The mesh size of the net is 2 cm. The cages are 3 × 4 × 4 m in size.

Open frame floating cages are adopted because this design is easy to manage. However, this national design standard does not regulate the layout of the cages. The high density of the cages at the site may produce decreased water exchange and may therefore induce cross-infection with disease as well as the accumulation of residual amounts of drugs. The process is identified as a critical control point.

Water quality

The water quality associated with the culture system directly affects the safety of the aquaculture product (Hamblin and Gale, 2002). The potential hazards resulting from poor water quality include chemical and biological pollution. The primary sources of chemical pollution are near the cage culture site. Runoff from the nearby farms may contain agrochemicals, insecticides and heavy metals. Moreover, these harmful chemical contaminants can migrate through the food chain, accumulate in the body of *S. scherzei*, and subsequently threaten the health of the human consumers. The potential biological hazards to the culture system are mainly associated with pathogens and parasites. Pathogens infect *S. scherzei* and cause disease. Some pathogens can also infect humans. For example, during the initial aquaculture period, the pathogens of Chilodenella and Trichodina can infect *S. scherzei*, which can also infect humans. Owing to the low exchange rate of the water, any remaining excess feed in the system will deteriorate rapidly and may trigger infections by pathogens. Moreover, waterfowl may carry pathogens and may therefore represent a potential source of biological hazards. The process is identified as a critical control point.

Supply of fry and domestication

The fish fry are obtained from wild-caught fish. Before the wild fish fry placed in the culture cages, they are put in a small tank for acclimatization for approximately a month. They are then housed in standard cages for feeding. In this process, the culturist does not make strict demands on the quality of fish fry. The fish fry may carry pathogens and parasites. Biological pollution is the main hazard. The process is identified as a critical control point.

Supply of feedstuffs

Biological and chemical pollution are the main causes of the hazards that generate the need for proper attention and control. The origin of these hazards is that, the feed used for *S. scherzei* in the cages consist of bait (small dead fish and shrimp). The bait may be contaminated with a variety of pathogens and parasites that if not treated, can induce outbreaks of diseases that are particularly high during May to September. Therefore, the process is a critical control point.

Disinfection of cages

Prior to stocking and during the breeding process, disinfection of cages must be performed in a way that does not introduce hazards to the culture. The culture cages are treated by using bleaching powder twice a month. In addition, allitridi (at 100 g allitridi per 200 small fish) is added to the cages at a rate of 10 times per year. Chemical compounds or disinfectants that are used in compliance with good aquaculture practises will not produce chemical contamination in the water and will therefore not harm the consumer (Song et al., 2011). Hence, the proper use of the abovementioned disinfectant during the breeding process will not harm the culture. The process is not a critical control point.

Use of drugs to prevent and cure disease

In this aspect of *S. scherzei* aquaculture, the drugs used for disease treatment represent the main hazard that requires control. The primary sources of this hazard are that, the culturist lacks knowledge of the use of drug and that antibiotics may be abused in the culture process. The antibiotics then accumulate inside the body of *S. scherzei*. This situation may lead to the appearance of drug-resistant pathogens. The human body is susceptible to the pathopoietic functions that these pathogens induce. For example, chloromycetin is used to treat human and fish diseases. But if this antibiotic reaches humans through the food chain, it may induce the appearance of drug-resistant pathogens. The use of this drug in fish culture may therefore be potentially harmful to human health. Furthermore, malachite green and methylene blue can prevent and cure wheel verminosis and water mildew if these compounds are used properly. However, malachite green is highly toxic and is carcinogenic to humans. The process is identified as a critical control point.

Daily management regime

The potential hazards in the culture system are pathogenic fungi and helminthes. These potentially harmful organisms need to be controlled through good management practises. The source of this hazard is that, small fishes used as feed are not disinfected before they are introduced to the cage culture in Zhelin Lake. If they are contaminated, these small fishes may cause pathogen infection in *S. scherzei*. Rapid growth of *S. scherzei* is observed from June to September when the temperature is high. Many diseases and pathogens are particularly likely to thrive when the temperature is high and when the fish are growing rapidly. Poor management of aquaculture and of poultry farms may cause disease and death to *S. scherzei* by introducing potentially harmful organisms to the cage culture. The process is identified as a critical control point.

Transportation

The harvest is transported to Qingdao and sold to middlemen. The product is subsequently exported to South Korea. Hazards that may arise during transport are physical injury and the growth of pathogenic fungi. However, these hazards are not CCPs because good practise can result in effective control. Professional carrier vehicles are used to transport aquatic products, and the workers possess good technical skill.

Establishment of critical control points (CCPs)

This study has identified the CCPs for the *S. scherzei* cage culture (Table 1). The study conducted a hazard analysis and investigated cage dimensions, stocking densities, the environment surrounding the culture site, supply of fish fry, use of drugs to prevent and cure disease and the supply of feedstuffs. These investigations indicated that, design and construction of the base, water quality, supply of fry and domestication, supply of feedstuffs, use of drugs to prevent and cure disease, and daily management regime were the CCPs associated with the process of culturing *S. scherzei*.

Establishment of critical limits for each CCP

In accordance with relevant regulations, applicable criteria and technical literature and practical experience, critical limits were defined in a way that would result in effective control of the hazards. The critical limits can be defined by a limitation index for product security or by the implementation of control factors in the production process to ensure product safety. The critical limits for the cage aquaculture of *S. scherzei* were established based on the regulations governing aquatic products established by China and by South Korea (Table 2).

Implementation of a monitoring system

Monitoring measures, which focus on the CCPs are one of the most important components of the HACCP plan for *S. scherzei* cage aquaculture. The monitoring system of the cage aquaculture of *S. scherzei*, including monitoring method and frequency, are established, and the personnel responsible are identified on the HACCP worksheet (Table 2). Effective monitoring measures can be adopted to determine whether the situation at a critical control point is out of control or deviates from the critical limits.

Establishment of corrective actions

When the monitoring indicates that, a particular CCP is not under control, an established corrective action must be taken. An overview of possible corrective actions is provided in Table 2.

Establishment of effective record keeping procedures

Record keeping is one important aspect of the implementation of the HACCP system. The preparation and the implementation of the HACCP plan should be recorded completely, and the records should include all the amendments and rectifications that have been adopted. All records should be kept for two years in document form, and they should be made available for evaluation and checking by the relevant monitoring department of the government (Table 2).

Establishment of procedures for verification

The technician feeding *S. scherzei* in the breeding

Table 1. Hazard analysis of cage culture of *S. scherzeri.*

The processing step	Potential hazards	Significant hazard, or not	Primary causes of the hazard	Preventive measures	CCP status of this processing step
Design and construction of the site	Biological: potential pathogenic microbes and parasites Chemical: heavy metals and drug residues	Significant hazard	The national design standards do not regulate the layout of the cage, However, density of the cages in the site is high	The choice and construction of cages should meet the state standard	CCP
Water quality	Biological: potential pathogenic microbes and parasites Chemical: heavy metals and drug residues	Significant hazard	The water quality will be degraded. Pathogenic organisms will be bred. Pesticides, fishery drugs, and heavy metals are introduced from the adjacent pollution sources and by the cultivation processes. These chemical contaminants may cause the appearance of resistant pathogens	Choose a satisfactory water source, purify and disinfect the water, clean up the feed-borne trematodes, intermediate hosts and pathogens	CCP
The supply of fish fry and domestication	Biological: potential pathogenic microbes and parasites	Significant hazard	The fish fry and bait are not effectively disinfected. The cultivation density is overly high	Adopt strict disinfection measures for the fish fry and bait, use moderate cultivation densities	CCP
Feed supply	Biological: potential pathogenic microbes and parasites Chemical: heavy metals	Significant hazard	The bait might be polluted by heavy metals. It may introduce massive infestations of pathogenic bacteria or parasites. The bait might be not fresh during the hot season	Apply strict disinfection procedures for the fish bait and supply fresh fish bait	CCP
Disinfection of cages	Chemical: chemical residues	Not significant	The proper use of the abovementioned disinfectant during the breeding process will not harm the culture		Not
Use of drugs for prevention and cure of disease	Chemical: drug residues	Significant hazard	The abuse of the fish drug	Purchase and use the medication permitted by national or international standards. Do not use illicit drugs, such as malachite green and the like. Read the instructions carefully before applying the treatment	CCP
Daily management regime	Biological: potential pathogenic microbes and parasites Chemical: drug residues	Significant hazard	Unscientific management of cultivation	Use appropriate timing and quantitative feeding. Remove all surplus bait in a timely manner. Isolate fish showing signs of illness in time to prevent an outbreak	CCP
Transportation	Physical: abrasion	Not significant	Professional carrier vehicles are used to transport aquatic products, and the workers possess good technical skill		Not

Table 2. Identification and monitoring of important process phases (ranked as CCPs) in the cage culture of *S. scherzei.*

Critical control points (CCPs)	Significant hazard	Specifications/critical limits	Monitoring method and frequency	Corrective action	Recordkeeping	Proof process
Design and construction of the site	Biological: potential pathogenic microbes and parasites Chemical: heavy metals and drug residues	NY/T5167-2002 (environmentally friendly food, the technological norm of the breeding process for mandarin fish)	After the site has been built, checking whether the design and construction are unreasonable	Rebuilding the site	Drawing(s) of the site made for planning purposes	Checking the plan drawing of the site and investigating the construction conditions present at the site
Water quality	Biological: potential pathogenic microbes and parasites Chemical: heavy metals and drug residues	NY5051-2001 (environmentally friendly food, water quality for fresh water aquaculture)	Laboratory tests of water quality every month	Improving the protocol used for water quality analysis protocol, elimination of helminths, cleaning of cages to prevent blinding sieve	Results of the tests used to assess the water quality of the samples	Check the water quality test results, sample to verify the test results
The supply of fish fry and domestication	Biological: potential pathogenic microbes and parasites	NY5071-2001 (environmentally friendly criteria for the use of drugs in food fish) NY5073-2006; (environmentally friendly food for ensuring restricted level of poisonous and harmful materials in aquatic products); Items and criteria for the inspection and quarantine for the entry and exit of aquatic animals for South Korea	Microbiological laboratory analyses every month	Discarding poor-quality fry, selection of high-quality fry	Test results from fry sampling	Check the test results, sample to verify the test results
Feed supply	Biological: potential pathogenic microbes and parasites Chemical: heavy metals	NY5073-2006 (environmentally friendly food for ensuring restricted levels of poisonous and harmful materials in aquatic products)	Microbiological and chemical laboratory analyses every month	Selection of high-quality bait if sampled fry is found to be of poor quality and is rejected	Test results from bait sampling	Check the results of the tests made on the bait, sample to verify the test results
Use of drugs for prevention and cure of disease	Chemical: drug residues	NY5071-2001 (environmentally friendly criteria for use of fish drugs); NY5073-2006 (environmentally friendly food for ensuring restricted levels of poisonous and harmful materials in aquatic products); NY5070-2002 (Restricted levels of fish medicine remain in aquatic product); Items and criteria for inspection and quarantine for the entry and exit of aquatic animals for South Korea	Chemical laboratory analyses every month	Purchasing drugs that comply with national or international standards and using dosage strictly as recommended, and confirming decontamination after use of the drug	Test results from fish sampling	Check the results of the tests made on fish, sample to verify the test results
Daily management regime	Biological: potential pathogenic microbes and parasites Chemical: heavy metals	NY/T5167-2002 (environmentally friendly food, the technological norm of the breeding process for mandarin fish)	Checking cages regularly every day	Adopting a standard procedure for feed management	The records obtained from the procedures used for checking cages	Checking the cage records and reviewing the management operations

facility generates an appropriate summary of the breeding technique. The purpose of this report is to confirm that, each CCP has been controlled, that the situation at the critical point is sufficient to ensure food safety in the process of breeding *S. scherzei* and that, the HACCP system is functioning effectively. Validation of the result should reveal whether or not the measure adopted for the purpose is correct (Table 2).

Conclusion

There is interest worldwide in the implementation of the HACCP system by the food industry, especially for high-risk foods such as meat, poultry or fishery products (Lupin et al., 2010; Wang et al., 2010). The HACCP system is based on a scientific, systematic, rational, multi-disciplinary, and cost-effective approach to the control of safety problems (Song et al., 2011). The countrywide establishment of HACCP and of a traceability system in China has gradually enhanced the security of aquatic products across the whole production chain from aquaculture, processing, and distribution to consumption. The safety and quality of aquatic products should be ensured beginning at the headstream.

This study applied the HACCP system to the cage aquaculture of *S. scherzei*. Chemical and biological contaminants were two of the main hazards identified by the analysis. A variety of factors could lead to pollution by these agents. The chemicals of concern consisted of antibiotics, hormones and minerals. Antibiotic use is of concern because the antibiotic may affect non targeted species and thus, produce antibiotic resistance and other toxic effects (Cole et al., 2009). Microbiological contaminants are of concern because diseases and parasites can be deleterious. Parasites may serve as a vector for other lethal diseases, such as infectious salmon aenemia (ISA).

ISA has been detected in farmed and wild fish (Cole et al., 2009). The CCP decision tree in the HACCP system was activated and executed. These computations identified six CCPs. The CCPs identified by the decision tree were design and construction of the site, water quality, supply of fish fry and domestication, feed supply, use of drugs for prevention and cure of disease and culture system. Corrective actions were immediately taken at each CCP. Implementation of the HACCP system helped to improve the chemical and biological quality of the cage aquaculture of *S. scherzei*. However, it should be pointed out that, the success of the system does not depend exclusively on the fact that, the HACCP process produced promising results regarding chemical and microbiological contaminants. The significance of the results is that, they help to indicate whether or not the HACCP system is working effectively.

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