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Optimization of Soft-Shell Crab Production: Implementation of Appropriate Technology Through Integrated Cultivation Container (ICC)

Iskandarsyah[1], Evayani[2], Evi Mutia[3*], Dian Tamara Nasution[4]
Universitas Syiah Kuala
Corresponding Author: Evi Mutia evimutiafe@usk.ac.id

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A B S T R A C T

This community service project aims to enhance the efficiency and productivity of soft-shell crab farming by implementing the Integrated Cultivation Container (ICC) as an appropriate technology solution. The ICC was designed using locally sourced materials in Aceh to reduce production costs while improving cultivation processes. The project employed a participatory approach, involving local farmers to ensure practical adoption and sustainability. Outcomes include increased production efficiency, comprehensive training modules, and secured intellectual property rights. Future recommendations emphasize capacity building, government and private support, further technological refinement, and program replication, ensuring sustainable, long-term impacts on coastal communities and the fisheries sector.

INTRODUCTION

Soft-shell crab cultivation is becoming an increasingly prominent sector in aquaculture, driven by the rising demand for high-quality seafood (Wamnebo and Yusuf 2023); (Ahmad Baparki 2023). Soft-shell crabs (Scylla spp.), known for their soft exoskeleton during the molting phase, are favored globally for their tender texture and rich nutritional content (Agustiyana et al. 2024). The growing consumer preference for premium seafood has positioned soft-shell crab farming as a lucrative industry with significant market opportunities. Therefore, it is deemed necessary to encourage farmers and business actors to engage in this cultivation activity (Kurniawan et al. 2022). Indonesia is a major player in the global soft-shell crab trade, with Asia receiving 81% of the country's total exports (Jolpano et al., 2023). In 2022, China was the leading export destination for Indonesian crabs, with a value of USD 51.12 million, equivalent to 6.95 million tons, followed by Malaysia, Japan, the United States, and Singapore. This strong export market underscores the importance of scaling up production to meet international demand.

The Indonesian government has shown its commitment to supporting soft-shell crab farming by issuing strategic policies, including Minister of Marine Affairs and Fisheries Regulation Number 7 of 2024 on the Management of Lobsters (Panulirus spp.), Soft-Shell Crabs (Scylla spp.) and Blue Crabs (Portunus spp.). However, achieving sustainable cultivation requires more than regulatory support. There is an urgent need for innovative and appropriate technology to address technical and operational bottlenecks faced by farmers. This community service project addresses these issues through the development and implementation of the Integrated Cultivation Container (ICC). The ICC technology is designed to optimize the farming environment by improving water circulation, controlling environmental parameters, and enhancing disease prevention. By utilizing locally available materials in Aceh, this solution also aims to reduce production costs and make the technology accessible to small-scale farmers.

In addition to introducing technological innovations, this project emphasizes capacity building for farmers. Practical training and workshops are conducted to enhance farmers' knowledge of sustainable cultivation practices, farm management, and disease control. Empowering farmers with the necessary skills and technology is crucial for improving productivity and ensuring the long-term viability of soft-shell crab farming in the region. The implementation of the ICC technology offers a novel contribution to the aquaculture sector by addressing critical challenges in soft-shell crab farming. By fostering sustainable and efficient farming practices, this initiative not only supports local economic development but also contributes to meeting the growing global demand for soft-shell crabs. Through this comprehensive approach, the project aims to establish Aceh as a leading hub for sustainable soft-shell crab production.

In response to the increasing market demand, PT. King Soka Indonesia, a company founded in 2019 with the tagline "Capit Indonesia dari Aceh," is focusing on developing the Integrated Cultivation Container (ICC) technology for sustainable soft-shell crab farming. The company is engaged in providing production services for brackish-water aquaculture and aims to build partnerships with various stakeholders in the soft-shell crab industry, from upstream to downstream. PT. King Soka Indonesia's goal is to become a leading MSME in the development of the blue economy downstream, with a focus on empowering the soft-shell crab commodity, particularly in Indonesia. As an MSME, PT. King Soka Indonesia possesses several key strengths, including vast market potential, mastery of sustainable farming techniques, and the capability to provide the necessary infrastructure and facilities for aquaculture. By leveraging Indonesia's abundant coastal resources, the company is globally oriented and strives to optimize the potential of soft-shell crabs as a premier commodity from the country.

However, despite the significant economic potential of soft-shell crab farming, farmers continue to face several challenges, including diseases and parasites, poor water quality, difficulties in selecting high-quality breeding stock, improper pond management, competition with other species, dependence on natural breeding, the impacts of climate change, and a general lack of knowledge and skills among farmers. Diseases such as bacterial, viral, and fungal infections can reduce the survival rate of crabs, while poor water quality adversely affects their health and growth. Furthermore, challenges in selecting quality breeding stock and suboptimal pond management can significantly impact production outcomes.

To address these challenges, a comprehensive approach is necessary. This includes the implementation of sustainable farming practices, routine health monitoring of crabs, and targeted training for farmers on best practices in aquaculture. One promising solution is the application of appropriate aquaculture technology, such as the Integrated Cultivation Container (ICC), which aims to increase efficiency in soft-shell crab farming. Consequently, this community service program is expected to make a significant contribution to enhancing the sustainability of soft-shell crab farming in both economic and environmental terms.

Through partnerships with PT. King Soka Indonesia and the adoption of suitable technologies, it is hoped that soft-shell crab farmers will be better equipped to overcome various challenges and maximize their production potential. This program focuses not only on increasing output but also on improving the quality and sustainability of soft-shell crab farming, ultimately contributing positively to the local economy and strengthening Indonesia's position as a major player in the global soft-shell crab industry.

The implementation of the ICC technology offers a novel contribution to the aquaculture sector by addressing critical challenges in soft-shell crab farming. By fostering sustainable and efficient farming practices, this initiative not only supports local economic development but also contributes to meeting the growing global demand for soft-shell crabs. Through this comprehensive approach, the project aims to establish Aceh as a leading hub for sustainable soft-shell crab production.

IMPLEMENTATION AND METHODS

The implementation and service process is designed to address the challenges in soft-shell crab farming through a well-structured, multi-phase approach. The activities will take place in Aceh over a six-month period, involving a diverse group of approximately 25 participants. These participants include local soft-shell crab farmers, business incubator students, and representatives from PT. King Soka Indonesia. With their varied backgrounds in aquaculture, the participants are well-equipped to effectively integrate the training and technology into existing practices.

At the outset, a comprehensive problem analysis will be conducted to assess the current issues faced by the partners. This initial phase focuses on identifying challenges such as the limitations of the Crab Apartment concept, high ammonia levels, and elevated production costs. Data collection through surveys and on-site evaluations will provide a clear picture of the operational difficulties. Following this, an extensive research and literature study will be undertaken to explore existing solutions, review relevant case studies, and confirm the abundance of local mineral materials in Aceh, all of which will inform the subsequent stages of the project.

The next step involves the development of the Integrated Cultivation Container (ICC). Drawing on insights gained from the problem analysis and research, the ICC is designed to be context-specific, taking into account local environmental conditions, available materials, and the financial capacity of the farmers. Once the design is finalized, the ICC will be implemented on a pilot basis in selected aquaculture sites. This phase involves the practical installation of the technology and its integration into the daily operations of local crab farms, ensuring that it effectively addresses issues such as ammonia build up while reducing overall production costs.

Training and mentoring are integral components of the project, ensuring that the participants are equipped to utilize and maintain the new technology. Hands-on workshops and regular training sessions will be provided to familiarize the farmers with the ICC and updated cultivation methods. This capacity-building effort is supported by ongoing mentoring, which will help the participants to troubleshoot issues and adopt best practices in sustainable aquaculture.

Finally, a robust monitoring and evaluation system will be established to track the performance of the implemented solution. Regular site visits and data collection on key indicators, such as ammonia levels, crab survival rates, and cost efficiency, will enable the project team to assess the effectiveness and sustainability of the ICC. Feedback from the participants will be continuously gathered to inform iterative improvements, ensuring that the technology remains effective and is adapted to any emerging challenges.

RESULTS AND DISCUSSION

Overview of the Integrated Cultivation Container (ICC) Implementation

It is well known that soft-shell crab farming is commonly conducted in open areas using floating cages by coastal farmers. However, harvest outcomes are greatly affected by climatic factors (such as rainfall and local water habitat conditions), which can result in a scarcity of soft-shell crabs during high-demand periods such as Christmas, New Year, and Chinese New Year. In line with the high demand during these times, significant price fluctuations are inevitable. To increase soft-shell crab production, the innovative appropriate technology applied in this project is the Integrated Cultivation Container (ICC). The ICC technology is an innovative solution for soft-shell crab farming that integrates various critical aspects of the crab's life cycle into a single, controlled unit.

The ICC technology is specifically designed to address common challenges in soft-shell crab farming, such as high mortality rates, poor environmental quality in cultivation areas, and time-consuming, costly maintenance processes. The ICC optimizes space, water, and other resources, ensuring that the crabs remain in ideal conditions for growth and molting.

Key features of the ICC include:

1. An automated temperature and water quality control system that ensures the cultivation environment consistently meets the biological needs of soft-shell crabs.
2. A modular design that allows production capacity to be adjusted based on available space and specific requirements.
3. A sensor-based monitoring system that provides real-time data on crab health, water quality, and other environmental parameters.

The implementation of ICC technology is expected to enhance the efficiency, productivity, and environmental sustainability of soft-shell crab production, while also improving the welfare of coastal communities through increased yields and reduced risks of losses in crab farming.

Implementation of Activities

This invention begins by forming a supporting pillar structure and storage racks, which are then assembled and arranged vertically to create the pond framework. The materials used are readily available, durable, and corrosion-resistant, ensuring overall stability of the structure. This framework is designed to be robust enough to support each level of the pond and withstand the water pressure as well as the weight of the cultured biota. Next, PVC sheets are cut to size and installed on the floor and walls so that the pond is not only functional for cultivation but also visually appealing, making it suitable for display in public spaces or commercial areas. Afterward, tarpaulin is cut to the proper dimensions and secured onto the rack, followed by the construction of the filtration media rack (25) in a manner similar to the pond framework, with wheels attached to facilitate easy removal during maintenance.

The following step involves assembling the inflow and outflow piping systems. The inflow pipe is connected to a pump (30) using a 1⁄2″ pipe, while the outflow pipe is connected to the filtration media using a 1″ pipe. The flow pattern for both the inflow and outflow is established for each level: water is pumped in and then immediately discharged into the filter chamber. This design is intended to prevent ammonia contamination and the spread of diseases. The filtration media (refer to Figure 4) is a crucial component that is integrated into the overall aquaculture system. Within this media, several filter chambers are included, with their capacities precisely calculated for each individual pond unit.

The filtration system itself is composed of multiple layers of media, including fishing nets and coarse beach sand that contains coral fragments, shell debris, and floating stones. These layers function to capture particles and maintain water cleanliness, while also preserving essential mineral content parameters in the water such as Calcium (Ca), Magnesium (Mg), and silica (Si) which are vital for the growth and molting of crabs.

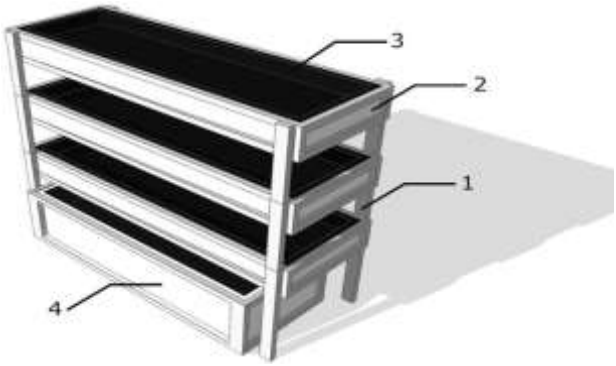

Figure.1 Integrated Cultivation Container (ICC)

The integrated design and technology applied per 10 units create a controlled environment that can prevent mass mortality caused by diseases or filtration failures often encountered in previous cultivation methods. This approach simplifies the maintenance process during the 15-30 day cultivation period and facilitates ideal monitoring during the soft-shell crab harvest.

This method involves the following steps: First, a multi-tiered pond is prepared, consisting of a lightweight steel frame, PVC walls and floor, and tarpaulin to create an ideal environment for soft-shell crab growth. Pond construction includes building the frame, walls, pond floor, and filtration basin; assembling each component of the ICC pond according to the assembly instructions; installing the tarpaulin, outflow pipes, and inflow pump; and setting up the filtration media, followed by maturing the aquaculture water by adding probiotics. Next, water circulation is regulated using an integrated water filtration system that includes both a filter and a pump, ensuring that water quality remains stable and supports the health of the crabs. Additionally, water levels are controlled using an adjustment pipe equipped with specific perforations to automatically manage the water height and slow down the water flow during power outages. Finally, the system facilitates the monitoring of aquatic biota and simplifies pond maintenance by maintaining the necessary water parameters, ensuring that the environment remains optimal for the crabs.

Impact of Activities

The implementation of the Integrated Cultivation Container (ICC) technology in soft-shell crab production is expected to yield numerous positive impacts for both the community and the environment, particularly in coastal areas targeted by this initiative. With the ICC's integrated and more efficient design, the productivity of soft-shell crab farming is anticipated to increase significantly. The controlled environment provided by the ICC optimizes the crabs' molting process, resulting in enhanced production in terms of both quantity and quality. The automatic monitoring and control system for temperature, salinity, and water quality within the ICC helps maintain ideal growth conditions for the crabs. This system minimizes the risks of mortality caused by environmental fluctuations or diseases that are common in conventional farming methods. Furthermore, the ICC technology enables more efficient management of water and space resources by integrating several stages of the cultivation process into a single controlled unit, thereby reducing operational costs related to water, energy, and feed. This improved efficiency supports the sustainability of soft-shell crab farming operations.

Increased productivity and production efficiency directly contribute to higher incomes for soft-shell crab farmers, as stable, high-quality yields open up broader market opportunities at both local and national levels. Additionally, the environmentally friendly nature of the ICC technology is expected to lessen the impact on the surrounding ecosystem. By promoting sustainable practices such as minimizing waste, maintaining water quality, and reducing the use of harmful chemicals the technology supports a more ecologically balanced approach to aquaculture. The project also has a positive impact on the knowledge and capacity of local communities. By introducing modern aquaculture techniques and technical skills through the ICC, farmers are better equipped to expand their operations and compete in broader markets. Moreover, the artistic and flexible design of the ICC, along with its ease of maintenance and monitoring, helps reduce capital and production costs while enabling its application in diverse locations. Ultimately, this initiative is poised to transform soft-shell crab farming

into a more efficient, sustainable, and profitable industry, thereby contributing to the overall economic well-being of coastal communities.

Challenges Encountered

Implementing the Integrated Cultivation Container (ICC) technology to optimize soft-shell crab production presents several challenges, both technical and non-technical. Many soft-shell crab farmers remain accustomed to conventional methods, which makes it difficult for them to understand and operate the more advanced ICC system. Consequently, effective knowledge transfer and comprehensive training become critical to ensure that the technology is used optimally.

Although the ICC technology promises long-term efficiency, the initial investment required for the equipment and infrastructure can be a significant barrier, especially for farmers with limited capital. Additionally, the ICC must be adapted to local environmental conditions such as climate, water quality, and weather patterns since variations in these factors can affect the system's overall effectiveness. This necessitates careful adjustments and field testing to achieve optimal performance.

Regular and proper maintenance is essential to preserve the functionality of the ICC. However, a lack of technical know-how regarding maintenance, coupled with limited access to spare parts or experienced technicians, may hinder the system's reliability if malfunctions occur. Furthermore, the ICC heavily relies on electricity to operate its automated control systems for monitoring water quality and regulating temperature. In coastal areas that often experience power supply disruptions or have limited infrastructure, this dependency poses a significant challenge to the continuity of aquaculture operations.

Resistance to change is another obstacle; some farmers may be reluctant to adopt new technologies, particularly if they are comfortable with traditional methods. Changing mindsets and demonstrating the tangible benefits of ICC technology will require a persuasive and time-intensive approach. Moreover, there is a gap in human resource preparedness, as many students involved in this community service project, especially during practices like seed preparation and mangrove crab cultivation, lack the skills to properly clean crabs from contaminants.

Lastly, external factors such as climate change, natural disasters, or government regulations that do not support coastal aquaculture could also impact the successful implementation of ICC technology. For example, flooding or rising sea levels might damage cultivation facilities or compromise water quality within the ICC system. Addressing these challenges will require a holistic approach that involves collaboration among government entities, academic institutions, and industry stakeholders to support and ensure the successful implementation of ICC technology within the community.

Availability of the Integrated Cultivation Container (ICC).

This invention comprises a lightweight steel frame that serves as the primary structure to support the pond walls and floor, and it is designed to be portable for easy assembly and disassembly. PVC sheets are used for the walls and floor to provide an aesthetically pleasing appearance, making the pond visually attractive in various settings. A tarpaulin functions as a flexible water container, and PVC pipes serve as channels for water circulation, connecting the inflow and outflow and controlling the water level.

Figure.2 Integrated Cultivation Container (ICC) Pond

The method associated with this invention involves several key steps: First, a multi-tiered pond is prepared, consisting of a lightweight steel frame, PVC walls and floor, and a tarpaulin to create an ideal environment for soft-shell crab growth. Pond construction includes building the frame, walls, pond floor, and filtration basin; assembling each component of the ICC pond according to the assembly instructions; installing the tarpaulin, outflow pipes, and inflow pump; and setting up the filtration media, followed by maturing the aquaculture water with the addition of probiotics. Next, water circulation is regulated using an integrated water filtration system that incorporates both a filter and pump to ensure stable water quality and support crab health. Water levels are automatically controlled using an adjustment pipe fitted with specific perforations to manage water height and decelerate flow during power outages. This system also facilitates the monitoring of aquatic biota and simplifies pond maintenance by maintaining the necessary water parameters for an optimal crab environment.

The construction process begins with forming support pillars and storage racks, which are then assembled and arranged vertically to form the pond framework. The materials chosen are easily obtainable, durable, and corrosion-resistant, ensuring the overall stability of the structure. This frame is robust enough to support the pond on every level and withstand the water pressure along with the cultured biota. Subsequently, PVC sheets are cut to the appropriate size and attached to the pond's floor and walls, enhancing both functionality and visual appeal for potential display in public or commercial areas. The tarpaulin is then cut to size and secured to the rack, followed by the construction of the filtration media rack in a similar manner to the pond frame, with wheels attached for ease of removal during maintenance.

The next step involves assembling the inflow and outflow piping. The inflow pipe is connected to the pump using a ½" pipe, while the outflow pipe is connected to the filtration media using a 1" pipe. The flow pattern is set up for each level so that water is pumped in and immediately directed into the filter chamber, which helps prevent ammonia contamination and disease. The filtration media, a vital component of the integrated aquaculture system, contains several filter chambers with capacities calculated for each pond unit. This filtration system comprises multiple layers of media (including fishing net and coarse beach sand enriched with coral fragments, shell debris, and floating stones) that capture particles and maintain water cleanliness, while preserving essential mineral content such as calcium (Ca), magnesium (Mg), and silica (Si) necessary for crab growth and molting.

Availability of a Training Module for Soft-shell Crab Aquaculture Using the Integrated Cultivation Container (ICC)

The training module is an essential component of the educational activities designed to ensure smooth implementation and achievement of the training objectives. The "Soft-shell Crab Aquaculture Training Module Using the Integrated Cultivation Container (ICCM)" has been developed to serve as a reference guide for conducting training sessions by both government training institutions and independent community programs.

Registration of Intellectual Property Rights (HAKI) for the Soft-shell Crab Aquaculture Training Module Using the Integrated Cultivation Container (ICC)

The registration of intellectual property rights for this training module is aimed at protecting the innovations and knowledge generated through this initiative in soft-shell crab aquaculture using ICC technology. By securing the intellectual property rights, the training module is not only protected but also positioned to make a more significant contribution to the sustainable development of soft-shell crab farming. These outcomes collectively illustrate the practical advancements achieved during the community service period, demonstrating both technological innovation and capacity building that contribute to the sustainability and profitability of soft-shell crab aquaculture in coastal areas.

CONCLUSIONS AND RECOMMENDATIONS

Soft-shell crab cultivation using the Integrated Cultivation Container (ICC) is a modern, technology-based method that enables aquaculture practitioners to manage crabs in a controlled and efficient environment. With its innovative design that integrates a system per 10 units, the ICC addresses various limitations of conventional ponds such as high initial costs, disease risks, and maintenance challenges while enhancing the efficiency of vertical space utilization.

ICC technology supports efficiency, productivity, and sustainability through an environmentally friendly approach, yielding significant impacts including increased capacity among aquaculture practitioners, the development of comprehensive training modules, and the protection of intellectual property rights. However, challenges such as limited technological knowledge, high initial investment costs, and dependency on electricity require special attention. The success of this program underscores the importance of collaboration among academics, government, and the community in supporting the implementation of appropriate technology in the fisheries sector.

Based on the outcomes and challenges encountered during this project, several recommendations are proposed to enhance and expand the use of Integrated Cultivation Container (ICC) technology in soft-shell crab farming. It is crucial to enhance the capacity of aqua culturists by organizing regular training workshops, technology transfer sessions, and mentoring programs to improve their skills and technological literacy in operating and maintaining the ICC system, while also involving more farmers to broaden the program's benefits and foster stronger collaboration.

Support from government and stakeholders is essential; thus, governmental agencies and financial institutions should explore options for subsidizing the initial investment costs to lower financial barriers, and partnerships with the private sector should be encouraged to assist with funding, marketing, and distribution. Further technological development is recommended through continuous evaluation of ICC technology to enhance its effectiveness and efficiency, including the exploration of alternative or backup energy sources, such as solar power, for areas with limited electricity, and the development of digital-based systems, such as real-time monitoring applications, to facilitate easier data access and accurate condition monitoring.

Additionally, replicating the program in other regions with potential for soft-shell crab cultivation and disseminating the results through journals or other media will help inspire and inform a wider community of stakeholders in the fisheries sector. Strengthening collaboration among academia, government, and industry stakeholders, along with ongoing monitoring and evaluation to promptly address emerging issues, will ensure that the optimization program for soft-shell crab production using ICC technology has a sustainable, long-term impact on coastal communities and the fisheries sector as a whole.

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