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Revolutionizing Aquaculture: First Successful Pearl Formation in Manipur Using Indigenous Mussels (*Lamellidens* spp.)

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ABSTRACT: This study represents the first report of pearl formation in freshwater mussels, *Lamellidens* spp. from Manipur, India, highlighting the feasibility of sustainable pearl farming practices in the region. Pearl farming is a promising aquaculture practice with significant economic and ecological potential, yet it remains underexplored in northeastern India, including Manipur. This study investigates the possibilities of pearl culture using indigenous freshwater mussels, *Lamellidens* spp., collected from Waithou, Thoubal district in Manipur. A total of 100 mussels were acclimatized and surgically implanted with nuclei to evaluate pearl formation, survival, and growth performance. Mussels were cultured under controlled conditions, with water quality parameters closely monitored to ensure optimal growth. After six months of culture period, 74% of the mussels survived, and 90% successfully retained the implanted nuclei, forming nacre layers indicative of pearl development. Growth performance showed an average shell length increase from 8.98cm to 9.32 cm. The pearls produced were predominantly half-round, with high lustre, minimal surface imperfections, and an average diameter of 4.3 mm (nacre thickness 0.3mm). The findings highlight the potential of *Lamellidens* spp. for sustainable pearl farming, offering a low-cost and viable aquaculture practice to enhance rural income and promote biodiversity conservation. This study supports the development of pearl farming clusters in Manipur as an alternative livelihood strategy, integrating economic growth with ecological preservation.

Keywords: Pearl farming, *Lamellidens* spp., Sustainable aquaculture, Freshwater mussels, Nacre formation.

INTRODUCTION

Pearl farming is an ancient aquaculture practice with global economic significance, particularly in countries such as Japan, China, and India (Southgate, 2008; Saurabh *et al.*, 2021). Pearls have been highly valued as symbols of beauty and wealth, contributing significantly to the economies of major pearl-producing countries (Pandey and Singh 2015; Zhu and Jin 2023). Despite its global importance, pearl farming has largely remained underexplored in northeastern India, including Manipur. This region, located within the Indo-Burma biodiversity hotspot, hosts rich aquatic biodiversity, including freshwater bivalves with significant potential for aquaculture (Allen, 2010).

Freshwater mussels, particularly species of *Lamellidens* such as *L. marginalis* and *L. corrianus*, are well known for their strong shell structure and ability to form high-quality nacre layers (Misra *et al.*, 2009; Birunagi *et al.*, 2013; Saurabh *et al.*, 2021; Suman *et al*., 2021). These features make them excellent candidates for pearl culture. Research conducted in various regions of India, including West Bengal and Uttar Pradesh, has shown the potential for pearl production using *Lamellidens* species (Rathor, 2017; Chakraborty *et al.*, 2023). These mussels offer promise for advancing sustainable pearl aquaculture, especially in rural areas where cost-effective methods are crucial for widespread adoption.

Manipur's vast network of freshwater resources, including rivers, lakes, and ponds, offers a unique opportunity to develop pearl farming as an alternative form of aquaculture. With a predominantly agrarian economy, the state faces challenges related to unemployment and over-reliance on traditional farming practices. Pearl farming presents a viable alternative to address these issues by providing sustainable livelihoods and supplementing rural incomes. It also complements traditional aquaculture practices, offering scope for integrated systems that promote biodiversity conservation while enhancing economic returns. The prospects of pearl farming in Manipur are particularly promising due to the abundance of indigenous mussel species and favourable climatic conditions. Pearl farming is a widely practiced and lucrative industry globally; however, it remains underexplored in Manipur, a financially underprivileged state in India. Despite the potential benefits, the adoption of this technique in the region is hindered, likely due to a lack of scientific awareness and dissemination of relevant

knowledge. Establishing pearl farming clusters could transform rural economies, attract investment, and generate employment opportunities, particularly for women and marginalized groups (Mikhailovich, 2021; Yadav and Sharma 2022). Moreover, the integration of pearl farming with eco-tourism and handicraft industries could further boost economic development.

The significance of this research lies in its potential to address the dual challenges of economic development and biodiversity conservation. Pearl farming not only provides a sustainable income source for rural communities but also promotes the conservation of indigenous mussel species by integrating them into aquaculture systems. The objectives of this study were to assess the feasibility of pearl farming using local *Lamellidens* species, optimize surgical implantation techniques, evaluate survival and growth rates, and explore pearl farming as a viable aquaculture practice to generate income and create employment opportunities.

MATERIALS AND METHODS

A. Study Site

This study was conducted at natural earthen ponds, covering an area of 5.0 square meters. The ponds provided a controlled and favourable environment for aquaculture activities, characterized by stable water quality, ease of access, and the availability of natural food sources essential for mussel growth. Water quality parameters were routinely monitored to ensure optimal conditions, with dissolved oxygen levels maintained between 5.0 and 8.0 mg/L, pH ranging from 7.0 to 8.5, and temperature regulated between 24°C and 28°C to support mussel growth and pearl formation.

B. Collection and Selection of Mussels

Approximately 100 healthy freshwater mussels belonging to the genus *Lamellidens* spp. (average shell length of 8-10 cm) were collected from Waithou, Thoubal district during the months of June and July, 2024 in Manipur (Figure 1A and B). Healthy mussels were manually collected and immediately transported in aerated containers to minimize handling stress. Upon arrival, mussels were screened for shell integrity, size (>8 cm to 10 cm shell length), and absence of parasites to ensure suitability for pearl farming.

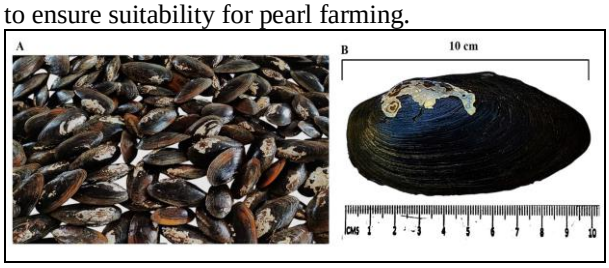

Fig. 1. (A) *Lamellidens* sp. utilized for pearl formation. (B) *Lamellidens* sp. with a shell length of 10 cm used for pearl production.

C. Pre-Conditioning

The healthy mussels were selected and subjected to a two-week acclimatization period in a controlled pond environment to minimize physiological stress and optimize their readiness for surgical implantation. During this period, the mussels were provided with algae-rich water as a natural food source to support their nutritional needs. The health of the mussels were closely monitored throughout the acclimatization period, with regular assessments for signs of stress, abnormal behaviour, and mortality. This pre-conditioning process was crucial for stabilizing the mussels and ensuring their suitability for surgical procedures and subsequent pearl formation.

D. Surgical Implantation

The surgical implantation process commenced with the sterilization of half-round nuclei, 4 mm in diameter, procured from SuperChoice, Delhi (Fig. 2A). These nuclei served as the starting point for pearl formation. The implantation involved inserting the nucleus into the mantle cavity of the mussel, a method selected for its simplicity and suitability for rural aquaculture practices. To ensure aseptic conditions, all surgical tools were sterilized with 70% ethanol prior to use. The nuclei were carefully implanted into the mantle cavity using precision surgical instruments, aiming to minimize tissue damage and enhance retention rates (Fig. 2B).

Fig. 2. (A) Nuclei (4 mm in size) used for pearl formation; (B) Process of nuclei implantation into the mantle cavity.

E. Post-Operative Care

Following implantation, mussels were transferred to an aquarium tanks (1 m length, 0.5 m width, and 0.4 m height) equipped with aerators to ensure adequate oxygenation. Mussels were treated with the broad-spectrum antibiotic chloramphenicol for seven days at a concentration of 1 mg/L, administered twice daily, to prevent post-operative infections. Additionally, 60% of the water in the tanks was replaced daily to maintain hygiene and water quality. Mussels were observed daily for signs of infection, mortality, and stress, and any debris in the tanks was promptly removed.

F. Pearl Harvesting

Pearl formation was monitored over a six months culture period, with nacre deposition recorded for 20 healthy mussels. The pearls were evaluated based on shape, size, lustre, and nacre quality. Statistical analyses were performed to assess survival rates and growth performance.

RESULTS

The pearls produced were primarily blister pearls, which form attached to the inner shell surface (Fig. 3). After six months of culture period, clear nacre deposition, a key indicator of pearl formation, was observed (Fig. 3). Nacre was deposited around the nucleus or beads in both valves (Fig. 3A and B). The

six months culture period yielded promising results in terms of survival, retention, growth performance, and pearl quality. Out of the 100 mussels initially used, 74 (74%) survived, demonstrating high adaptability and tolerance to the experimental conditions. Retention rates were equally positive, with 90% of the mussels successfully retaining the implanted nuclei, while only a small number expelled the inserted beads. Throughout the culture period, all mussels remained healthy. Water quality parameters, including temperature, pH, and dissolved oxygen levels, were carefully monitored and maintained within optimal ranges to support favourable growth conditions.

Growth performance was assessed in 20 healthy mussels dissected for pearl formation. These mussels exhibited consistent growth patterns, as reflected in steady increases in shell length. The initial shell length (mean ± SD) was 8.98 ± 0.61 cm, which increased to 9.32 ± 0.60 cm after six months of culture. The observed growth rate was positively correlated with water quality parameters and the availability of natural food, supporting optimal mussel development. Shell length measurements indicated an average growth increment of 0.34 cm in mussels implanted with nuclei, demonstrating comparable growth rates across experimental groups.

Pearl quality though at the early stage of pearl formation was evaluated based on shape, size, lustre, and surface imperfections, yielding highly favourable results. The pearls formed were predominantly half-round in shape, a characteristic highly desirable for jewellery applications. Pearl diameters averaged 4.3 mm, (nacre thickness 0.3 mm) with high lustre indicative of smooth and reflective nacre deposition, reflecting superior calcium carbonate deposition during the culture period. Surface imperfections were minimal, affecting less than 10% of the total pearls formed. The uniformity in shape, consistent size, and minimal defects suggest that the nuclei used in the study effectively supported optimal pearl formation processes.

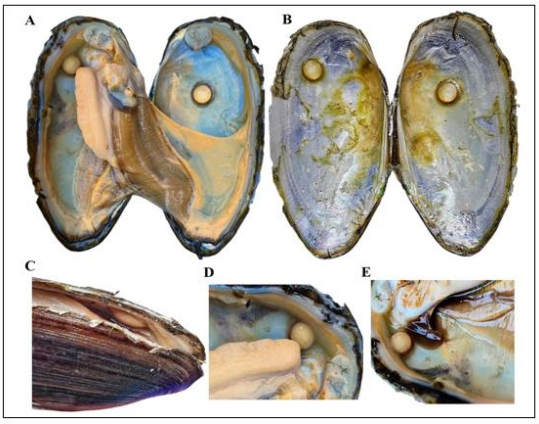

Fig. 3. Progression of pearl formation. (A) Nacre deposition during pearl formation with the flesh attached. (B) Demonstration of nacre deposition on the shells with the flesh removed. (C) Pearl forming between the inner shell layer and mantle. (D) Pearl formation in the right valve. (E) Pearl formation in the left valve.

This method employed, involving mantle cavity insertion, proved effective and feasible for rural aquaculture settings. The results demonstrated that *Lamellidens* sp. could be successfully used for pearl formation, providing a sustainable and low-cost alternative to traditional aquaculture practices.

DISCUSSION

The successful implementation of pearl farming using local freshwater mussels (*Lamellidens* sp.) in Manipur highlights the potential for sustainable aquaculture and rural economic development. This study serves as a foundation for integrating pearl culture into traditional aquaculture systems while conserving indigenous aquatic biodiversity. The study demonstrated high survival rates (74%) and promising retention rates for nuclei (90%), supporting previous findings on the suitability of *Lamellidens* species for pearl culture (Rathor, 2017; Saurabh *et al.,* 2021; Jacob *et al.,* 2022; Chakraborty *et al.,* 2023). The robust performance of mussels under experimental conditions underscores their adaptability to controlled environments and highlights their potential for commercialization. Furthermore, the observed growth rates and high-quality pearls align with outcomes from similar studies conducted in other parts of India (Rathor, 2017; Chakraborty *et al.,* 2023). The economic feasibility of pearl farming demands the production of high-lustre pearls with minimal defects required for jewellery markets. Additionally, pearl farming complements traditional fish farming, enabling farmers to diversify income sources without substantial additional investments.

Pearl farming integrates biodiversity conservation with economic development by promoting the use of native mussel species. Unlike invasive aquaculture practices, this approach fosters ecological balance and reduces dependence on non-native species (Bogan, 2008). Moreover, maintaining water quality and minimizing stress during pre-conditioning and post-operative care further support sustainable practices. While the preliminary results are promising, several challenges need to be addressed for large-scale adoption. The six months culture period produced primarily blister pearls, which are less valuable than free pearls. Extending the culture durations to over one year is necessary to enhance pearl size and quality (Tanu *et al.,* 2022). Additionally, optimizing surgical implantation techniques and post-operative care protocols can improve retention rates and reduce mortality.

This study highlights the socio-economic benefits of pearl farming, particularly for rural communities in Manipur. By creating employment opportunities and promoting skill development, pearl farming can empower marginalized groups, including women, to participate in the income-generating activities. Integrating pearl farming with eco-tourism and handicraft industries further expands market opportunities, enhancing its economic viability.

CONCLUSIONS AND FUTURE SCOPE

This study highlights the potential for pearl farming in Manipur, as pearls were successfully formed using local mussels during this preliminary investigation. Notably, no prior studies on pearl farming using native mussels have been conducted in Manipur, possibly due to unexplained reasons. The successful formation of pearls in this study paves the way for Manipur to become a pioneer in sustainable aquaculture. The implementation of pearl farming using local freshwater mussels (*Lamellidens* sp.) can mark a significant achievement, contributing to the region's economic development and the promotion of sustainable aquaculture practices. The high survival rates, consistent growth performance, and formation of pearls (nacre deposition around the nucleus) underscore the feasibility of utilizing *Lamellidens* species for commercial pearl culture. This initiative demonstrates not only the biological viability of pearl farming in Manipur but also its economic potential as a sustainable livelihood option, particularly for rural communities. Future research should focus on optimizing surgical implantation techniques, improving post-operative care, and extending culture durations to enhance pearl quality and yield. Long-term studies are required to assess the impacts of environmental factors, genetic selection, and feed supplementation on mussel health and pearl formation. Additionally, integrating pearl farming with eco-tourism and the handicraft industry has the potential to enhance economic benefits while simultaneously preserving cultural heritage and raising environmental awareness. Expanding production capacity and implementing farmer-training programs will be pivotal for ensuring widespread adoption, thereby driving economic development and promoting sustainable aquaculture practices in the region. Collaborative efforts among researchers, policymakers, and stakeholders will be essential to realize the full potential of pearl farming in Manipur and contribute to the broader goals of rural development and biodiversity conservation.

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Conflict of Interest. None.

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