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Transforming agribusiness for enhanced farm economy through pearl farming in India

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Abstract
This study examines the potential for transforming India's pearl farming industry by analyzing practices from China and formulating strategic recommendations. Employing a mixed-methods approach, data was gathered through primary sources like interviews with farmers and training institutions, as well as secondary sources including case studies and market reports. Key challenges in India, such as high risks, long culture durations, and limited adoption of advanced techniques, were identified. Comparative analysis revealed that China's dominance stems from superior mussel species, dual cultivation strategies, and advanced nucleation techniques. In contrast, India's underutilized resources and fragmented practices hinder growth. Strategies for India include adopting dual cultivation leveraging its climatic diversity, introducing superior mussel species, and encouraging extended cultivation periods. Supply chain mapping, based on information from entities like UAS, GKVK, and other training institutes, highlighted gaps in stakeholder coordination. The study emphasizes the importance of collaboration with organizations like NFDB and ICAR to facilitate research, training, and financial support. By implementing these practices, India can enhance the size and quality of pearls, improving global competitiveness and market value. This research contributes to the discourse on sustainable aquaculture development and proposes actionable measures to establish India as a key player in the global pearl market.

Keywords: Pearl farming, benefit-cost ratio, supply chain mapping

Introduction

A pearl is a hard, round object that is shiny and usually creamy-white in colour. Pearls form inside the shell of an oyster and are commonly used for creating expensive jewellery. They are highly valued for their lustre, which refers to the unique glow that seems to come from within the pearl. This quality distinguishes pearls from other gemstones, giving them a distinctive, elegant appeal (Bosshart *et al*., 1993) [6]. The shine of a pearl is another critical attribute, reflecting light in a way that enhances its visual allure. The beauty of pearls lies in their simplicity and natural origin, making them timeless pieces that have been cherished for centuries. Pearls are not only prized for their aesthetic qualities but also for the sense of sophistication and grace they bring to jewellery. Pearl farming, a fascinating and lucrative venture, offers substantial business opportunities for entrepreneurs willing to delve into the intricate world of aquaculture. The cultivation of pearls, primarily through oysters, involves meticulous care and precise techniques to produce high-quality gems. This sector has seen significant growth due to increasing demand for pearls in the fashion and jewellery industries. Modern advancements in pearl farming technology have made it more accessible and efficient, reducing the time and risk traditionally associated with pearl production. Additionally, the sustainable nature of pearl farming aligns with the growing consumer preference for eco-friendly products. Exploring this field reveals a blend of traditional practices and innovative approaches, promising both economic benefits and a unique connection to marine life. By understanding the nuances of pearl cultivation, aspiring pearl farmers can tap into a market that values both beauty and sustainability.

How Pearls are farmed?

Pearls are formed inside the shells of certain molluscs, such as oysters and mussels, when an irritant, such as a grain of sand or a parasite, becomes trapped inside. The mollusc secretes layers of nacre, also known as mother-of-pearl, around the irritant to protect itself (Aoki, 1959) [3]. This nacre is composed of aragonite or calcite, both crystalline forms of calcium carbonate, and a protein called conchiolin, which binds the crystals together. Over time, as more and more layers are added, the irritant is transformed into a smooth, lustrous pearl (Jin and Li, 2017) [5]. The process can take several years, with the quality and size of the pearl depending on various factors, including the type of mollusc, the water conditions, and the length of time the pearl has to develop. Cultured pearls are formed through a similar process, but human intervention is involved, where a small bead or piece of tissue is deliberately inserted into the mollusc to initiate the formation of the pearl. This method allows for greater control over the size, shape, and quality of the pearls produced.

History of Pearl Farming

The science of getting an oyster to cultivate a pearl began in the early 1900s in Japan. Kokichi Mikimoto, considered the father of the modern cultured pearl industry, began experimenting with nucleating Akoya pearl oysters and was finally successful in cultivating pearls after nearly a decade of experimentation. At about that same time, a government biologist, Tokichi Nishikawa and a carpenter, Tatsuhei Mise had both been working with pearl formation and also successfully nucleated the Akoya pearl oyster (Birunagi *et al*., 2013) [4]. The special grafting needle that Mise invented was granted a patent in 1907. Meanwhile, Nishikawa applied for a nucleation patent of his own, and discovered Mise's patent in the patent office. They united for their common goal, and created the Mise-Nishikawa method which is still what most grafting technicians use today. Mikimoto took their method a step further by adding a step of his own to create perfectly round Akoya pearls, and this

altered patent was granted to Mikimoto in 1916. He then proceeded to create the Mikimoto Pearl Company, and began spreading cultured pearls around the world. Actual whole pearl production didn't begin in China until the 1970's when it flooded the markets with small, crinkly-textured pearls known as 'Rice Krispie' pearls due to their appearance.As the decades have passed however, Chinese cultivation technology has rapidly improved. Today, whole, round Freshwater pearls are available that rival the saltwater Akoya pearl in luster, shape and smooth, blemish free surfaces - at nearly half the cost. Freshwater pearls are available in a variety of natural colors such as pink, peach, lavender, white and shades in between.

Types of Pearl

Pearls can be broadly categorized into natural, cultured, and artificial types. Natural pearls form without any human intervention when an irritant accidentally enters a mollusc, leading to the secretion of nacre over time. These pearls are rare and highly valued due to their organic origin and unique beauty. Cultured pearls, on the other hand, are produced through human assistance by inserting a small bead or tissue into a mollusc to stimulate nacre production. This method allows for more predictable and abundant pearl production, making cultured pearls more accessible and varied in shape and size. Artificial pearls, often made from materials like glass or plastic, are manufactured to mimic the appearance of natural pearls but lack the same lustre and quality. They are typically used in costume jewellery as a more affordable alternative to real pearls.

Fresh Water Mussel Species

- ***Lamllidens marginalis*:** It is among the most preferred freshwater species used as food by ethnic groups in Nepal, India and Bangladesh. It is found in lower and upper gangetic plains in India, Myanmar, Nepal and Sri Lanka. They are used for freshwater pearl farming in various states of India because of the good nacre formation inside the body.

- ***Lamllidens corrianus*:** It is a freshwater species found in sand, silt and mud substrate of large lowland rivers, ponds and dams. This species prefers lotic water bodies with a very rich macro zoo benthic community

- ***Parreysia corrugata*:** It is another freshwater species which is capable of producing pearls. It shows nomadic movements as it keeps moving from one place to another place on regular basis. The outer shell colour of this is mostly green in colour and the surface of this mussel is quite smooth. Nacre formation in this mussel is quite similar to Lemllidens Marginalis and Lemllidens Corrianus.

Marine Oyster Distribution

Marine pearls are produced form the species distributed in the Gulf of Mannar, Palk Bay, southern Kerala and Gulf of Kutch and the black lip pearl oyster, in the Andaman and Nicobar Islands. Technology for marine pearl production was developed by the CMFRI. Based on these developments, many large-scale commercial ventures and societal programmes were initiated near natural pearl oyster beds, particularly in Tamil Nadu and Kerala. However, due to several logistic reasons (primarily long duration of culture and risks of sea-based farming), these ventures could not sustain. Currently, there is no commercial production of cultured marine pearls in the country as reported by the ICAR-CMFRI. National developmental agencies like NFDB and State Fisheries Depts shall involve in promoting freshwater pearl culture technology to the end users as the reach of research institutes with limited manpower capacity is limited. ICAR-CMFRI and ICAR-CIFA can be the partners with these agencies in providing technical backstopping.

Objectives

1. To analyse the cost and returns in pearl farming business
2. To map the supply chain of the pearl farming business

Materials and Methodology

This study employs a mixed-methods approach, combining primary and secondary data to provide a comprehensive analysis of India's pearl farming industry and draw comparisons with China.

Data Collection

Primary data was collected during July 2024 through structured interviews and surveys with training institutions, and contract farming models. The study gathered insights into existing practices, challenges, and opportunities within India's pearl farming sector.

Sample size: The primary data to find the cost and returns and supply chain map is collected from 5 pearl farming training institutes:

- Inland Fisheries Unit, UAS, GKVK, Bangalore
- Indian Pearl Culture Training Institute
- Pearl Culture Training Centre, Kolkata
- D.R. Pearl Farm Pvt. Ltd.
- Glitterati Pearl Farms & Training Institute

Benefit-Cost ratio

The Benefit-Cost ratio is used to summarize the relationship between the benefits and costs of a proposed project.

$$\text{Benefit-Cost ratio} = \frac{\text{Present value of benefits expected from the project}}{\text{Present value of costs of the project}}$$

If a project's BCR is greater than 1.0, the project is expected to deliver a positive net present value.

Results and Discussion

The cost analysis (Table 1) of the pearl farming operation highlights the economic considerations of initiating a freshwater pearl farming setup. With a total investment of ₹40,000, comprising both variable and fixed costs, the study evaluates the feasibility and economic viability of this venture. The variable costs accounted for ₹29,000, representing 72.5 per cent of the total expenditure. This category is dominated by the cost of freshwater mussels at ₹3,000, which are critical as their quality directly influences pearl production outcomes.

Table 1: Cost of FW Designed Pearl Production for 3000 L Tank

Sl. No.	Particulars	Quantity	Value (₹)
I	Variable cost		
1	Cost of FW mussels	300	3000
2	Cost of embossed acrylic images	600	9000
3	Cost of marking mussels & implanting images into mussels	-	1500
4	Cost of labour	55 days	13750
A	Total variable cost	-	29000
II	Fixed cost	-	
1	Cost of tank (3cu.m., Height limited to 0.75m)	-	9050
2	Cost of shade net	-	750
3	Cost of suspending mussels in water	-	1200
B	Total fixed cost	-	11000
III	Total cost (A+B)	-	40000

Note: FW = Fresh water

The cost of embossed acrylic images, amounting to ₹9,000, highlights the technological input required for designer pearls. Labour costs, totalling ₹13,750, represent the largest share (47.4% of variable costs), reflecting the labour-intensive nature of mussel management and nucleus implantation. The high proportion of variable costs underscores the need for operational efficiency, particularly in reducing labour expenses through mechanization or skill development. Fixed costs totalled ₹11,000, forming 27.5 per cent of the overall cost. Significant contributors included tank construction, which required ₹9,050, ensuring optimal water quality and flow conditions for mussels, and shade nets costing ₹750, which provide protection from direct sunlight and maintain a conducive environment for mussel health. Fixed costs, although lower than variable costs, represent initial infrastructure investments that require careful planning to ensure long-term utility and scalability. The overall cost structure demonstrates the potential for profitability if managed efficiently. For instance, reducing input costs such as labour or innovating nucleus materials could significantly enhance margins. Economies of scale achieved through larger production setups may offset the high initial infrastructure costs. By adopting integrated aquaculture practices or value addition strategies, farmers could optimize resource use and diversify income streams, increasing the operation's resilience against market fluctuations. Leveraging government subsidies or financial assistance schemes can lower the barriers to entry for small-scale farmers. This cost breakdown provides a baseline for prospective pearl farmers, aiding in budget planning and decision-making while emphasizing areas where innovation and cost optimization could drive greater profitability.

Table 2: Returns from pearl farming business

Sl. No.	Particulars	Quantity	Cost (₹)
1	Yield(n)	300 @ 50(%) Survival rate	-
2	Price (₹/ pearl)		300
3	Gross returns (₹)	-	90000
4	Net returns (₹)	-	50000
5	Benefit-cost ratio	-	1.25

The financial analysis of the pearl farming operation (Table 2) shows promising returns. With a survival rate of 50 per cent, the yield of 300 pearls reflects the initial success of the farming process. Given the price of ₹300 per pearl, the gross returns from the venture amount to ₹90,000. This indicates a solid market value for each pearl, highlighting the profitability potential within the pearl farming industry. After accounting for the operational costs, the net returns stand at ₹50,000, which suggests that despite the significant upfront and operational costs, the business remains financially viable. The benefit-cost ratio of 1.25 further supports the economic feasibility of the venture, indicating that for every ₹1 spent, the farmer receives ₹1.25 in return. This is a positive sign for investors, as the ratio exceeds 1, which means that the income generated from pearl farming exceeds the expenses involved. It also suggests room for improving efficiency, as small optimizations in the farming process, such as increasing the survival rate or improving labour efficiency, could significantly boost profits. Overall, the numbers highlight the potential of pearl farming to generate sustainable and profitable returns, especially if the operation is scaled or refined over time.

The supply chain map of pearls in India outlines the journey from inputs to consumers. Inputs such as mussels, nuclei, surgical instruments, nets, and algae are provided to producers. Producers then work with vendors and wholesalers, sending some products to labs for processing. Processors handle the pearls before passing them on to wholesalers, who distribute them to retailers and exporters. Retailers sell directly to consumers, while exported pearls go through additional processing and retailing before reaching international consumers. Imports also contribute to the supply chain, being distributed through producers and wholesalers to various downstream entities.

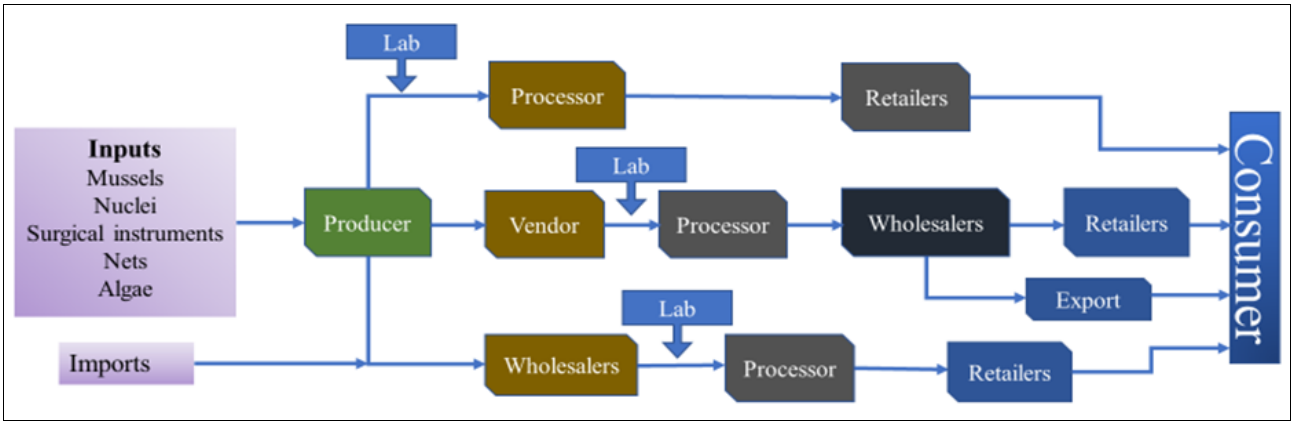

Fig 1: Supply chain map of pearl farming business

Comparison between Indian and Chinese Pearl Farming

China has established itself as a global leader in pearl farming due to its advanced techniques and strategic approaches, which India can learn from to enhance its pearl farming industry. The Chinese pearl industry leverages factors such as superior mussel species, innovative techniques, extended cultivation periods, and geographical advantages, which have propelled it to the forefront of global production.

One of the primary reasons for China's success is the use of superior mussel species such as *Hyriopsis cumingii* (triangle mussel), known for producing smooth, high-quality pearls ranging from 3-4 mm in size (Bai *et al*., 2013) [8]. India, on the other hand, has limited access to such advanced species and predominantly relies on local mussels, which may not yield comparable pearl quality or size. Collaborative efforts to domesticate and breed superior species suitable for Indian waters could bridge this gap.

China employs advanced nucleation techniques, particularly the mantle tissue implantation method, ensuring nuclei are placed accurately for uniform pearl development. This results in smoother, larger pearls (Scarratt *et al*., 2000) [7]. In contrast, Indian pearl farming often lacks precision in nucleation, primarily due to limited technical knowledge and inadequate infrastructure. To address this, India needs investment in modern nucleation tools, capacity-building programs, and training initiatives to improve technical expertise.

Another distinguishing feature of Chinese pearl farming is the extended cultivation periods of 4-6 years, facilitated by using younger mussels (1–1.5 years old). This practice enables the production of pearls exceeding 8 mm in size (Akamatsu *et al*., 2001) [2]. Indian farmers typically opt for shorter cultivation cycles to reduce economic risk, often compromising pearl size and quality. Providing financial support, subsidies, and awareness programs to encourage longer cultivation periods could help Indian farmers achieve better outcomes.

China's geographical diversity also plays a pivotal role. Warmer southern regions are utilized for the initial stages of pearl growth, where biomineralization is faster, while colder northern regions enhance the shininess of pearls through a slower biomineralization process. This dual cultivation strategy ensures larger, shinier pearls (Akamatsu *et al*., 2001) [2]. India, with its diverse climatic zones, has the potential to adopt a similar approach. Warmer southern regions can facilitate rapid growth, while cooler northern areas can enhance pearl luster. However, this would require infrastructure for transporting mussels and collaboration between regions to implement effectively.

To integrate these practices, India can focus on developing research programs to identify suitable mussel species, promoting advanced nucleation techniques, encouraging longer cultivation periods, and adopting dual cultivation strategies. Government schemes, subsidies, and collaborations with institutions like ICAR-CIFE could play a significant role in modernizing India's pearl farming industry, aligning it with global best practices observed in China.

Conclusion

The pearl farming industry in India holds immense potential for economic growth and sustainability, especially in states like Karnataka, which are endowed with rich natural resources and favorable climatic conditions for freshwater pearl cultivation. Despite the challenges posed by high risks, prolonged culture durations, and the absence of integrated aquaculture practices, the sector offers promising opportunities for transformation into a lucrative venture with strategic interventions. Advancements in pearl culture technology, such as precise nuclei positioning and improved nucleation techniques, are pivotal for enhancing the quality and yield of pearls. These technologies can significantly reduce the variability in pearl formation, resulting in smoother, larger, and higher-value pearls. Furthermore, India's geographical diversity provides a natural advantage for implementing dual cultivation strategies, where warmer regions can accelerate initial growth, and cooler regions can enhance luster and finish. Collaborative efforts with key organizations like the National Fisheries Development Board (NFDB) and the Indian Council of Agricultural Research (ICAR) can further catalyze the growth of the pearl farming industry. These partnerships can facilitate the development of superior mussel species, promote research on site-specific farming practices, and support capacity-building programs for farmers. Proper training, awareness, and investment in infrastructure are critical to overcoming existing barriers. By demonstrating the profitability of pearl farming through pilot projects and success stories, the sector can attract more stakeholders, including private investors and small-scale farmers. This, in turn, will diversify the agricultural economy and create sustainable livelihoods. India's pearl farming industry, if nurtured with the right mix of innovation, policy support, and market linkages, can emerge as a global competitor, adding significant value to the aquaculture sector and contributing to the broader agricultural economy.

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