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COMPARATIVE ANALYSIS OF TRADITIONAL AND INTENSIVE *LITOPENAEUS VANNAMEI* CULTURE SYSTEMS

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ABSTRACT

Shrimp aquaculture has undergone considerable development with the introduction of improved production technologies, particularly in the farming of Pacific white shrimp (*Litopenaeus vannamei*). Traditional culture systems generally depend on natural pond productivity, lower stocking densities and relatively limited external inputs, whereas intensive systems rely on higher stocking densities, formulated feeds, mechanical aeration, water quality monitoring and advanced biosecurity measures. Both systems have distinct advantages and limitations in terms of production efficiency, investment requirements, resource utilisation and environmental sustainability. This article compares traditional and intensive *L. vannamei* culture systems with respect to pond infrastructure, stocking density, feeding practices, water management, aeration, disease prevention, production performance and economic viability. Traditional systems offer relatively low production costs and are accessible to small-scale farmers, while intensive systems provide higher production per unit area but require greater technical expertise, capital investment and operational control. The comparison highlights the importance of selecting a suitable culture system according to farm resources, environmental conditions and management capacity. An integrated approach combining efficient resource utilisation with appropriate biosecurity and environmental management is essential for sustainable shrimp aquaculture.

Keywords: Shrimp Aquaculture Biosecurity, *Litopenaeus vannamei*, Sustainable Shrimp Farming

1. INTRODUCTION

Shrimp aquaculture is an important component of the global seafood industry and contributes significantly to employment, food security and export earnings. Among the commercially cultured shrimp species, Pacific white

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shrimp (*Litopenaeus vannamei*) has gained considerable importance because of its rapid growth, adaptability to different salinity conditions and suitability for a wide range of production systems. The expansion of shrimp farming has encouraged the development of different culture methods, ranging from traditional extensive systems to modern intensive and super-intensive production systems. Traditional farming generally depends on natural food organisms, tidal water exchange and relatively low stocking densities. In contrast, intensive culture involves higher stocking densities, nutritionally balanced formulated feeds, mechanical aeration, regular monitoring and improved biosecurity. The transition towards intensive production has been driven by increasing market demand, limited availability of suitable coastal land and the need to improve production per unit area. However, intensification also increases dependence on feed, electricity, skilled labour and water quality management. Therefore, understanding the differences between traditional and intensive systems is essential for selecting an appropriate farming strategy (Emerenciano et al., 2022).

2. OVERVIEW OF TRADITIONAL *L. VANNAMEI* CULTURE SYSTEMS

Traditional shrimp farming is generally associated with extensive and, in some cases, semi-intensive production systems. These systems commonly use large earthen ponds, relatively low stocking densities and natural pond productivity as an important source of nutrition. In extensive systems, shrimp growth depends considerably on phytoplankton, zooplankton, benthic organisms and other natural food resources. Fertilisation may be used to enhance natural productivity, while supplementary feeding is limited or absent. Water exchange is often based on tidal conditions or periodic pumping, and mechanical aeration is generally minimal. Semi-intensive systems represent an intermediate production approach. Hatchery-produced post-larvae are stocked at moderately higher densities, and formulated feed is supplied to supplement natural food. Some mechanical aeration and periodic water exchange may also be adopted. These systems require more management than extensive farming but generally involve lower capital investment than intensive production. Traditional systems are relatively simple to operate and may be suitable for farmers with limited financial and technical resources. However, production is more dependent on seasonal environmental conditions, natural food availability and water quality stability.

3. OVERVIEW OF INTENSIVE *L. VANNAMEI* CULTURE SYSTEMS

Intensive shrimp farming involves higher stocking densities and greater control over the culture environment. Production is generally carried out in relatively small, well-prepared earthen or lined ponds equipped with mechanical aerators, water distribution facilities and suitable drainage arrangements. The system depends primarily on complete formulated feeds to meet the nutritional requirements of shrimp. Feeding is generally conducted several times daily, with quantities adjusted according to shrimp biomass, growth and feeding response. Regular sampling is required to estimate average body weight and standing biomass. Water quality management is more intensive because increased feed inputs and shrimp biomass can result in higher oxygen demand and organic waste accumulation. Dissolved oxygen, temperature, pH, salinity, alkalinity, ammonia and nitrite require regular monitoring. Biosecurity measures such as screened water intake, quality seed procurement, equipment disinfection and controlled farm access are also essential. Advanced intensive systems may incorporate biofloc technology, recirculating aquaculture systems (RAS), lined ponds and automated monitoring equipment. These technologies can improve water utilisation and production control, but their success depends on skilled operation and reliable infrastructure (Emerenciano et al., 2022).

4. COMPARATIVE ANALYSIS OF TRADITIONAL AND INTENSIVE CULTURE SYSTEMS

4.1 Pond Infrastructure and Design

Traditional shrimp farms generally use large earthen ponds with comparatively simple inlet and outlet arrangements. Pond sizes and shapes may vary according to land availability and local water management practices. Infrastructure requirements are relatively limited. Intensive systems generally use smaller and more regularly shaped ponds to

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facilitate aeration, feeding, water circulation and sludge removal. HDPE-lined ponds are also used in some production systems to reduce sediment accumulation and improve control over pond-bottom conditions.

4.2 Stocking Density

Stocking density is one of the major differences between the two systems. Traditional extensive systems generally use low stocking densities, while semi-intensive systems adopt moderate stocking levels. Intensive systems use substantially higher densities and require corresponding improvements in aeration, feeding and water quality management.

4.3 Feeding Management

In traditional systems, natural pond organisms contribute significantly to shrimp nutrition. Fertilisation may be used to stimulate natural food production, and supplementary formulated feed is provided according to the production system. Intensive systems depend mainly on nutritionally complete commercial feeds. Feeding frequency, feed quantity and pellet size are adjusted according to shrimp growth and biomass. Feeding trays and regular sampling help reduce feed wastage and improve feed conversion efficiency.

4.4 Water Quality Management

Traditional systems generally depend more on natural processes, tidal exchange and periodic water renewal. Although water quality monitoring remains important, the frequency and technical requirements may be lower than in intensive systems. Intensive systems require frequent monitoring because higher feed inputs and biomass can increase ammonia, nitrite and organic matter accumulation. Aeration, controlled water exchange, sludge removal and, in some systems, microbial management are used to maintain suitable water conditions.

4.5 Aeration Requirements

Mechanical aeration is generally limited in traditional extensive systems, where photosynthesis and water exchange contribute to oxygen availability. Some semi-intensive farms use paddle-wheel aerators during periods of low dissolved oxygen. Intensive systems depend heavily on mechanical aeration. Paddle-wheel aerators and other oxygenation equipment are operated according to shrimp biomass and environmental conditions. Emergency power arrangements are essential because sudden aeration failure can result in rapid oxygen depletion and mortality.

4.6 Biosecurity and Disease Management

Traditional farms may have relatively limited physical and operational biosecurity arrangements, particularly where water is exchanged directly with surrounding water bodies. Disease prevention may depend heavily on seed quality, pond preparation and environmental conditions. Intensive systems generally require stronger biosecurity because higher stocking densities can increase the consequences of pathogen introduction. Screened and treated water, certified seed, crab fencing, equipment disinfection, controlled entry and regular health monitoring are important components. However, higher technology does not automatically guarantee better disease control. Poor management, contaminated inputs or inadequate water quality can still result in serious disease outbreaks in intensive systems.

5. COMPARATIVE PERFORMANCE OF TRADITIONAL AND INTENSIVE SYSTEMS

The following table presents indicative characteristics of extensive, semi-intensive and intensive *L. vannamei* culture systems. These ranges are general reference values from published literature and should not be treated as fixed standards for every farm.

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Parameter	Traditional extensive	Traditional semi-intensive	Intensive
Pond type	Earthen	Earthen	Earthen or lined
Typical pond area	Large, often 5–10 ha	Approximately 1–5 ha	Approximately 0.1–1 ha
Stocking density	1–10 PL/m²	10–30 PL/m²	40–70 PL/m² or higher
Main nutritional source	Natural food	Natural food and supplementary feed	Formulated feed
Feeding frequency	Limited or none	Usually 2–3 times/day	Usually 4–5 times/day
Aeration	Minimal or absent	Limited or supplementary	Regular mechanical aeration
Water exchange	Tidal or periodic	Periodic or controlled	Controlled, often reduced
Monitoring intensity	Relatively low	Moderate	High
Biosecurity requirement	Basic	Moderate	Strict
Indicative production	Around 0.15–0.5 t/ha/crop	Around 0.8–2.5 t/ha/crop	Around 3–8 t/ha/crop

Published descriptions of *L. vannamei* production systems indicate that extensive farming commonly uses low stocking densities and natural food resources, while intensive production depends on formulated feeds, substantial aeration and close environmental monitoring (FAO, n.d.; Emerenciano et al., 2022).

6. GROWTH, SURVIVAL AND FEED CONVERSION EFFICIENCY

Growth performance is influenced by seed quality, nutrition, stocking density, water quality and environmental stability. Traditional systems may support relatively slower growth because natural food availability and environmental conditions vary throughout the culture period. However, lower stocking densities may reduce competition and oxygen demand. Intensive systems can achieve higher production per unit area through regular feeding, improved aeration and better control of culture conditions. However, increased biomass also raises the risk of stress and poor feed utilisation if water quality and feeding are not properly managed. Feed conversion ratio is particularly important in intensive farming because formulated feed represents a major production cost. Traditional systems may use less commercial feed, but their productivity is generally lower. Therefore, FCR should be interpreted alongside feed inputs, survival and total production rather than as an isolated indicator of system efficiency.

7. ECONOMIC COMPARISON OF BOTH SYSTEMS

Traditional systems generally require lower initial investment because they involve simpler pond infrastructure, limited aeration equipment and fewer advanced monitoring facilities. Their operational expenditure may also be relatively low. However, lower production per hectare can limit total revenue. Intensive systems require higher investment in pond preparation, aerators, generators, quality seed, formulated feeds, water treatment and health monitoring. Electricity and labour costs are also greater. Nevertheless, higher production per unit area and the possibility of multiple production cycles may improve economic returns when the system is efficiently managed. The economic advantage of intensive farming depends on feed prices, electricity costs, seed quality, survival, market size

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and shrimp selling price. Resource-use studies have shown that intensification can improve production efficiency per unit of land, although it also changes energy, water and feed requirements (Boyd et al., 2021).

8. ENVIRONMENTAL SUSTAINABILITY

Traditional systems generally have lower input requirements and may produce less nutrient-rich waste per unit area. However, extensive land requirements, uncontrolled water exchange and poor farm drainage can still create environmental concerns. Intensive systems use more feed, energy and other production inputs per unit area. Excessive feed application and inadequate sludge management can increase organic loading and nutrient discharge. Untreated effluent may adversely affect surrounding aquatic ecosystems. On the other hand, properly managed intensive systems can improve resource-use efficiency through controlled water exchange, effective aeration, sludge removal and effluent treatment. Biofloc and recirculating systems offer additional opportunities for nutrient recycling and reduced water use, although they require more technical expertise and monitoring (Emerenciano et al., 2022).

9. SUITABILITY OF BOTH SYSTEMS FOR COASTAL ANDHRA PRADESH

Andhra Pradesh is one of India's major shrimp-producing states, with commercial farming concentrated in coastal districts such as Nellore, Prakasam, Bapatla, Krishna, West Godavari, East Godavari and Srikakulam. The region has established hatchery, feed, processing and marketing infrastructure that supports intensive *L. vannamei* farming. Traditional and semi-intensive systems may be suitable for farmers with limited investment capacity, larger pond areas and access to favourable natural water conditions. These systems can reduce dependence on electricity and advanced equipment, although production may be lower and more variable. Intensive systems are more suitable where farmers have access to quality seed, reliable electricity, adequate aeration, technical support and effective water treatment facilities. Seasonal rainfall and salinity fluctuations in coastal Andhra Pradesh make regular water quality monitoring particularly important. The selection of a production system should be based on local carrying capacity, water availability, financial resources, technical expertise and environmental regulations rather than production targets alone.

10. MAJOR CHALLENGES AND FUTURE OPPORTUNITIES

Traditional systems face challenges related to low productivity, seasonal variations, dependence on natural food and limited environmental control. Improving pond preparation, seed quality, supplementary feeding and basic biosecurity can enhance their performance without requiring complete conversion to intensive farming. Intensive systems face challenges related to high capital costs, electricity dependence, feed expenditure, disease risks and the need for skilled technical management. Automation, real-time water quality sensors, automatic feeders and digital farm records can improve operational efficiency. Future development should focus on sustainable intensification, in which production is increased without proportionately increasing environmental pressure. Integrated approaches combining improved genetics, efficient nutrition, biosecurity, microbial management and responsible water use can support more resilient shrimp production.

11. CONCLUSION

Traditional and intensive *Litopenaeus vannamei* culture systems differ considerably in their infrastructure, stocking density, feeding strategies, water management, aeration requirements, biosecurity and production output. Traditional systems offer lower investment requirements and relatively simple management, making them suitable for farmers with limited resources. Intensive systems provide greater production per unit area but require higher capital investment, skilled labour, regular monitoring and strict biosecurity. Neither system is universally superior; their suitability depends on farm resources, environmental conditions, market requirements and management capacity. For coastal Andhra Pradesh, a gradual transition towards scientifically managed and environmentally responsible production systems can improve shrimp productivity while reducing disease and financial risks. The long-term future

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of shrimp aquaculture will depend on balancing production efficiency with resource conservation and farm-level economic sustainability.

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