Research Article

Sustainable Economy

Sustainability and Competitive Advantage in Vannamei Shrimp Aquaculture: A Case Study of PT Graha Tambak Pinotu

Aris Jumadil, Sitti Aisya, Ferdiawan Ferdiawan

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Abstract: Intensive vannamei shrimp aquaculture significantly contributes to regional economies but may simultaneously generate environmental degradation and limited community integration, threatening long-term business sustainability. Strengthening sustainability-based management is therefore essential to maintain ecological balance and competitive performance within coastal aquaculture industries. This study aimed to analyze how integrated sustainability practices contribute to competitive advantage at PT Graha Tambak Pinotu, Central Sulawesi. A qualitative descriptive case-study approach was employed between May and July 2025 through in-depth interviews, field observations, and document analysis involving four stakeholder groups: company management, operational employees, local community representatives, and village authorities. Data were analyzed using thematic coding based on economic, social, environmental, and strategic sustainability dimensions. The findings demonstrate that the company institutionalizes sustainability practices across operational activities. Economically, production stability is supported through certified shrimp seed, controlled feed management, and digital water-quality monitoring systems, while feed costs remained within the estimated industry range of 50–70% of operational expenditure. Socially, the company employs more than 300 local workers and provides technical training in Good Aquaculture Practices (GAP), contributing to local income stability and workforce capacity development. Environmentally, wastewater is treated through sedimentation ponds, probiotic-based pond management reduces chemical dependency, and routine monitoring of temperature, pH, salinity, and ammonia concentration supports environmental stability. Expansion into national and export markets further strengthens business resilience and competitiveness. The study concludes that sustainability practices function as strategic resources that enhance operational efficiency, stakeholder legitimacy, and long-term competitive advantage within coastal aquaculture systems.

Introduction

Indonesia, as the world's largest archipelagic state, possesses extensive marine resources, with a coastline of approximately 108, 000 km and marine waters covering around 6.4 million km^2 (1). This maritime potential positions the fisheries and aquaculture sector as one of the strategic pillars supporting national economic development and coastal community livelihoods. Among aquaculture commodities, *Litopenaeus vannamei* (whiteleg shrimp) has become the dominant cultivated shrimp species due to its rapid growth rate, high productivity, adaptability to fluctuating environmental conditions, and strong market demand in both domestic and export markets. National fisheries statistics indicate that vannamei shrimp contributes significantly to Indonesia's aquaculture exports and constitutes the largest share of national shrimp production (2, 3). Consequently, vannamei shrimp aquaculture has become increasingly important not only as a source of foreign exchange earnings but also as a driver of regional economic growth in coastal areas.

However, the rapid expansion of intensive shrimp farming has also generated various ecological and social challenges. Intensive aquaculture systems are frequently associated with water pollution caused by organic waste accumulation, deterioration of coastal water quality, mangrove ecosystem degradation, and increased disease outbreaks resulting from environmental instability (4). In

many coastal regions, unsustainable pond management practices have reduced environmental carrying capacity and threatened the long-term viability of shrimp production systems. In addition to environmental issues, shrimp aquaculture operations that inadequately involve surrounding communities often create social inequality, limited local participation, and weak stakeholder acceptance. Such conditions may ultimately reduce operational legitimacy and hinder long-term business sustainability.

In response to these challenges, sustainability has become a central paradigm in contemporary aquaculture governance. The Triple Bottom Line (TBL) framework emphasizes the integration of economic viability, social responsibility, and environmental stewardship as the foundation of sustainable business practices (5). Within the aquaculture sector, sustainable shrimp farming is no longer interpreted solely as maintaining production output, but also as ensuring ecological balance, improving community welfare, and strengthening institutional resilience. Economically, sustainability supports production efficiency, stable profitability, and market expansion. Socially, sustainability encourages local employment, community empowerment, and stakeholder participation. Environmentally, sustainability requires effective waste management, responsible resource utilization, and continuous monitoring of ecosystem quality.

Previous studies have examined sustainability in shrimp aquaculture from several perspectives. Research on mangrove-based shrimp farming systems highlighted the importance of ecological sustainability indicators in maintaining production continuity (6), Other studies evaluated the implementation of Good Aquaculture Practices (CBIB) and demonstrated that standardized operational procedures improve environmental performance and business feasibility (7). Additional research assessed consumer satisfaction and operational sustainability in shrimp hatchery enterprises (8), while strategic management studies utilized tools such as the Competitive Profile Matrix (CPM) to analyze competitive positioning in shrimp-related industries (9). Nevertheless, existing studies generally examine sustainability and competitive advantage separately. Most research focuses either on environmental and socio-economic sustainability indicators or on competitive strategy analysis without integrating both dimensions into a single analytical framework.

This separation creates an important research gap. Empirical evidence explaining how sustainability practices directly contribute to the formation of firm-level competitive advantage in shrimp aquaculture enterprises remains limited, particularly in emerging aquaculture regions such as Parigi Moutong Regency, Central Sulawesi. Sustainability-oriented practices such as environmental compliance, technological innovation, stakeholder engagement, and community empowerment increasingly function as strategic resources capable of strengthening operational efficiency, market legitimacy, and long-term competitiveness. Therefore, examining sustainability as a strategic capability rather than merely a regulatory obligation becomes highly relevant in the context of modern aquaculture development. Accordingly, the central research problem addressed in this study is the limited empirical understanding of how sustainability implementation contributes to the creation of competitive advantage in vannamei shrimp aquaculture enterprises.

PT Graha Tambak Pinotu, established in 2023 in Toribulu District, Parigi Moutong Regency, represents a modern vannamei shrimp aquaculture enterprise operating in a coastal area with significant aquaculture potential. The company applies modern cultivation technology, employs local communities, and collaborates with village authorities in managing aquaculture activities. In addition, the company has implemented several sustainability-oriented practices, including wastewater sedimentation systems, probiotic-based pond management, digital water-quality monitoring, and workforce capacity development. Nevertheless, the extent to which these sustainability practices contribute to the company's competitive advantage has not yet been systematically examined.

Therefore, this study aims to analyze the sustainability of vannamei shrimp production at PT Graha Tambak Pinotu across economic, social, and environmental dimensions and to examine how these dimensions collectively contribute to the company's competitive advantage. Using a qualitative descriptive case-study approach, this research collected data through in-depth interviews, direct observation, and document analysis involving company management, employees, local community members, and village authorities. By positioning sustainability as a strategic business capability, this study contributes to the development of sustainable aquaculture literature and offers an integrative perspective linking sustainability performance with competitive advantage in coastal aquaculture enterprises.

Methodology

Study Design and Rationale

This study employed a qualitative descriptive case-study design to examine the sustainability of vannamei shrimp (*Litopenaeus vannamei*) aquaculture and its contribution to competitive advantage at PT Graha Tambak Pinotu, located in Pinotu Village, Toribulu District, Parigi Moutong Regency, Central Sulawesi. A case-study approach was selected because the research sought to generate an in-depth contextual understanding of sustainability practices within a single corporate setting, integrating economic, social, environmental, and strategic dimensions. This design is appropriate when investigating complex organizational phenomena embedded within real-life contexts, particularly where the boundaries between operational practices and stakeholder interactions are not clearly separated.

The analytical framework was grounded in the Triple Bottom Line (TBL) concept (5), which conceptualizes sustainability across three interrelated pillars: profit (economic viability), people (social responsibility), and planet (environmental stewardship). The study further incorporated the concept of competitive advantage as a strategic outcome derived from sustainability-oriented resource management and operational capabilities (10). By integrating these theoretical perspectives, the study aimed to examine how sustainability practices function not merely as compliance mechanisms but as strategic assets that enhance long-term competitiveness. This qualitative approach emphasizes an in-depth understanding of social

phenomena within their natural settings, allowing researchers to interpret meanings constructed by participants (11).

This qualitative case-study approach was considered appropriate because the research aimed to explore complex interactions between sustainability practices, stakeholder relationships, and strategic business performance that could not be adequately captured through purely quantitative measurement. Although the study focused on a single enterprise, the findings provide contextual insights into how sustainability-oriented management practices may contribute to competitive advantage and regional economic development within emerging coastal aquaculture industries. Therefore, the study offers analytical relevance beyond the immediate case by illustrating broader relationships between sustainability and business competitiveness in Indonesia's aquaculture sector.

The study area was selected because Parigi Moutong Regency is one of the coastal regions in Central Sulawesi with considerable potential for brackish-water aquaculture development, particularly vannamei shrimp farming. Toribulu District possesses coastal environmental characteristics suitable for intensive shrimp cultivation, including access to seawater resources and expanding aquaculture infrastructure. In recent years, shrimp aquaculture activities in the region have increased alongside growing economic interest in export-oriented fisheries commodities. Therefore, PT Graha Tambak Pinotu represents a relevant case for examining the relationship between sustainability practices and competitive advantage within an emerging coastal aquaculture region.

Population, Informants, and Sampling Criteria

The study population comprised stakeholders directly associated with the operational and social environment of PT Graha Tambak Pinotu, including internal management, operational employees, surrounding community members, and village government representatives. Purposive sampling was applied to select key informants based on relevance, knowledge, and direct involvement in the company's aquaculture activities.

A total of four primary informants were selected: 1) a Human Resources Development (HRD) representative involved in managerial and sustainability planning; 2) one operational shrimp pond employee directly engaged in production activities; 3) a local community member affected socio-economically by the company's presence; and 4) the Head of Pinotu Village representing local government authority. Inclusion criteria required informants to have at least one year of interaction or involvement with the company's operations to ensure adequate experiential insight. The sample size was deemed sufficient due to the depth-oriented nature of qualitative inquiry and the focused scope of the case study.

Data Sources, Materials, and Instruments

Data were derived from both primary and secondary sources. Primary data consisted of semi-structured, in-depth interviews and direct field observations conducted at the aquaculture site between May and July 2025. Secondary data included company reports, village administrative documents, regulatory references (e.g. , UKL-UPL documentation), and relevant statistical publications.

The principal research instrument was a semi-structured interview guide developed based on four analytical dimensions: 1) Economic sustainability variables, including employment generation, income stability, production efficiency, cost management systems, and market positioning; 2) Social sustainability variables, including local labor absorption, capacity building, stakeholder participation, and corporate social responsibility (CSR) initiatives; 3) Environmental sustainability variables, including waste management systems, biosecurity implementation, water quality monitoring (temperature, pH, salinity, ammonia concentration), use of probiotics, and sedimentation pond management; 4) Competitive advantage variables, including technological innovation, managerial efficiency, digital financial recording systems, adaptive strategic planning, and stakeholder trust-building mechanisms.

Observation tools included structured field notes documenting pond layout, sedimentation ponds, water discharge systems, aeration technology (energy-efficient paddle wheels), and biosecurity measures such as probiotic application and organic pond base treatment. All interviews were audio-recorded with consent and transcribed verbatim for analysis.

Research Procedures

The research procedure consisted of five sequential stages. First, preliminary engagement was conducted with company management and village authorities to obtain research permission and identify relevant informants. Second, field observation was carried out to map production facilities, including grow-out ponds, sedimentation ponds, water intake systems, and waste management infrastructure. Observation was conducted to obtain a real and contextual understanding of events and operational processes in order to answer the research questions effectively (12). Observational documentation focused on operational processes such as staged stocking of shrimp post-larvae (benur), feed management practices, water quality monitoring routines, and biosecurity protocols.

Third, in-depth interviews were conducted using open-ended questions designed to elicit detailed narratives regarding sustainability practices and strategic management. Each interview lasted approximately 60–90 minutes and was conducted in Bahasa Indonesia. Probing techniques were used to clarify perceptions regarding environmental management (e.g. , sedimentation ponds prior to discharge), workforce training, and digital bookkeeping systems implemented for cost and production monitoring.

Fourth, document analysis was undertaken to triangulate interview findings with written records, including CSR activities, UKL-UPL environmental compliance documentation, and internal production records. Finally, data were systematically organized into thematic matrices corresponding to the TBL framework and competitive advantage constructs.

Data Analysis

Data analysis followed an interactive qualitative analysis model comprising data reduction, data display, and

conclusion drawing/verification. During data reduction, interview transcripts were coded using thematic categorization aligned with economic, social, environmental, and strategic variables. Open coding was initially applied to identify emergent themes, followed by axial coding to establish relationships between sustainability practices and competitive outcomes.

Data display involved constructing analytical matrices linking sustainability indicators (e.g. , local employment rates, water filtration systems, probiotic usage, digital cost recording) with strategic outcomes such as operational efficiency, stakeholder legitimacy, and adaptive capacity. Interpretive analysis was then conducted to assess whether sustainability dimensions functioned as value-creating resources consistent with resource-based views of competitive advantage (10).

Credibility and trustworthiness were ensured through triangulation of sources (management, employees, community, village government), triangulation of methods (interview, observation, documentation), and member checking, whereby preliminary interpretations were validated with selected informants. Dependability was enhanced through detailed documentation of procedures and coding processes.

Ethical Considerations

Ethical principles were strictly observed throughout the study. Prior to data collection, formal permission was obtained from PT Graha Tambak Pinotu management and Pinotu Village authorities. All participants provided informed consent and were informed of the study's objectives, voluntary participation rights, and confidentiality assurances. Identifiers were anonymized in transcripts to protect participant privacy. Data were stored securely and used exclusively for academic purposes.

Results and Discussion

Sustainability of Vannamei Shrimp Aquaculture in Pinotu Village, Toribulu District

PT Graha Tambak Pinotu integrates sustainability principles into its operational framework by balancing economic productivity, social responsibility, environmental stewardship, and long-term strategic planning. This approach aligns with the core foundation of sustainable development, which pursues profitability, social welfare, and ecological integrity simultaneously (5). Empirical findings indicate that these sustainability practices are not just for operational compliance, but function as strategic mechanisms that support business continuity, institutionalized daily governance, and competitive resilience.

The sustainability of *Litopenaeus vannamei* aquaculture at the company was analyzed through four interrelated dimensions: economic, social, environmental, and strategic. This multidimensional framework mirrors previous Indonesian shrimp aquaculture studies, which prove that ecological, economic, social, technological, and institutional factors (13). Through structured pond management, technological innovation, and local workforce empowerment, these dimensions interact systematically, reinforcing prior research (6, 7) that sustainability-oriented practices simultaneously serve as operational safeguards and strategic economic assets.

Economic Sustainability

From an economic perspective, sustainability is reflected in the company's ability to maintain production stability, manage operational efficiency, and diversify market access. The findings indicate that economic sustainability at PT Graha Tambak Pinotu is not interpreted solely as short-term profitability, but rather as the capacity to sustain long-term production without compromising ecological and social resources. This interpretation aligns with the concept of sustainable aquaculture proposed by Widajanti (10), emphasizing the integration of economic continuity with responsible resource management.

One important operational strategy involves the use of certified, high-quality shrimp seed (*benur*) obtained from reputable hatcheries. Empirical evidence from corporate monitoring records indicates that the company maintains an optimal initial stocking density with a massive capacity of approximately 5, 000, 000 post-larvae (PL) per production cycle. Seed selection significantly affects survival rates, feed conversion ratio (FCR), growth consistency, and harvest quality. This finding supports previous aquaculture studies indicating that seed quality is a major determinant of production efficiency and financial return in intensive shrimp farming systems (7). By prioritizing high-quality post-larvae at the beginning of the production cycle, the company reduces mortality risk and minimizes production uncertainty, thereby improving operational stability.

Technological integration also contributes substantially to production efficiency. High-pressure aeration systems, automated water-quality monitoring, and controlled feed management improve oxygen distribution and optimize feed utilization. The findings indicate that feed efficiency constitutes a critical economic factor because feed expenses account for approximately 50–70% of shrimp production costs. By executing precise biomass-based monitoring, the company strives to maintain an optimal Feed Conversion Ratio (FCR) target below 1.2–1.3, preventing sub-optimal feeding and economic loss. Controlled feeding schedules and biomass monitoring therefore reduce waste accumulation while maintaining optimal FCR performance. Similar observations were reported in previous shrimp aquaculture studies, which found that technology-based feed management significantly improves cost efficiency and production sustainability.

Furthermore, the company has expanded into export-oriented market systems to reduce dependence on local demand fluctuations, improve revenue resilience in volatile commodity markets (8), and strengthen regional aquaculture value chains. Rather than pursuing aggressive production intensification, the management prioritizes "*quality-oriented growth*," recognizing that uncontrolled expansion without environmental safeguards can undermine future productivity. Consequently, economic sustainability in this framework is analytically linked to environmental protection and social stability, reinforcing the interconnected nature of the Triple Bottom Line framework (5).

Social Sustainability

PT Graha Tambak Pinotu drives social sustainability by employing over 300 active workers, with up to 80% predominantly originating from Pinotu Village and

surrounding sub-districts. These local workers are directly integrated into core operations, including feed management, water-quality control, and harvest logistics. This substantial labor absorption significantly stabilizes the local economy by transitioning community members from unstable informal employment to structured, wage-based labor, which increases household income stability. This structural shift supports previous sustainability studies emphasizing that equitable community involvement is a critical component of sustainable aquaculture development (6).

The study also found that workforce training programs function as an important mechanism of social empowerment. Employees receive technical training related to Good Aquaculture Practices (GAP), environmental monitoring, and biosecurity procedures. Such programs increase technical capability and operational professionalism among local workers. Salsabila and Zakiya (7) similarly reported that implementation of GAP standards improves not only production quality but also community-based aquaculture resilience and adaptive capacity.

Another important finding concerns institutional coordination with village authorities. Regular consultation and communication mechanisms create transparency regarding recruitment processes, operational expansion, and environmental management practices. Furthermore, the institutionalization of Corporate Social Responsibility (CSR) programs including direct economic assistance, local community empowerment initiatives, and infrastructural coordination serves as a primary instrument to balance corporate presence and local interests. From the perspective of stakeholder theory, such collaborative governance strengthens organizational legitimacy and reduces social conflict risk (10). In this context, social sustainability extends beyond employment creation and includes participatory governance, community trust-building, and long-term socio-economic transformation. Within a broader economic context, local workforce empowerment also contributes indirectly to regional economic circulation through increased household purchasing power and local business activity. Therefore, social sustainability practices implemented by PT Graha Tambak Pinotu generate wider developmental implications beyond internal company operations.

Environmental Sustainability

Environmental sustainability constitutes a critical dimension of shrimp aquaculture due to the ecological vulnerability of coastal production systems. Previous studies have shown that intensive shrimp farming is frequently associated with mangrove degradation, eutrophication, declining water quality, and coastal pollution (14, 15). The findings of this study demonstrate that PT Graha Tambak Pinotu attempts to minimize these ecological risks through structured environmental management practices.

One important environmental strategy involves the implementation of probiotic-based water treatment instead of chemical antibiotics. Informants explained that probiotics are routinely applied to maintain microbial balance, suppress pathogenic bacteria, and stabilize pond water quality. This practice reduces dependence on chemical inputs and supports environmentally responsible production systems. The findings therefore support previous studies emphasizing that biosecurity-oriented aquaculture management improves both environmental sustainability and product safety standards (7).

Wastewater management also emerged as a significant environmental safeguard. The company operates a dedicated Wastewater Treatment Plant (WWTP / IPAL) layout consisting of structured sedimentation and neutralization ponds before effluent discharge. Effluent water from shrimp ponds is processed through sedimentation ponds before discharge into surrounding waters. These sedimentation systems function as natural filtration mechanisms that reduce suspended solids and nutrient accumulation. Continuous monitoring of water-quality parameters such as temperature, pH, salinity, and ammonia concentration further enables early identification of ecological stress. Such preventive environmental management aligns with responsible aquaculture principles emphasizing continuous monitoring and ecological risk mitigation (6).

An additional finding concerns community perception regarding environmental management transparency. Village stakeholders reported that openness in wastewater processing and environmental monitoring increased public trust toward company operations. This demonstrates that environmental stewardship functions not only as ecological protection but also as reputational management supporting the company's social license to operate.

Analytically, these findings indicate that environmental sustainability contributes directly to long-term productivity stability. By maintaining ecosystem quality, the company minimizes disease outbreaks, reduces operational disruption, and lowers the risk of future regulatory sanctions. Consequently, environmental management in this case simultaneously functions as ecological protection, production risk management, and strategic business sustainability.

Strategic Sustainability

PT Graha Tambak Pinotu strengthens its strategic sustainability by transforming traditional compliance into a competitive business strategy that integrates operational efficiency, environmental management, workforce development, and market expansion. To mitigate production vulnerabilities caused by fluctuating input prices and environmental uncertainties, the company deploys efficiency-oriented systems, including energy-efficient paddlewheel aerators, controlled feed utilization, and digital monitoring systems. These technological integrations, paired with continuous workforce strengthening and strict environmental compliance, systematically elevate the company's adaptive capacity under changing market conditions.

Another core strategic component involves market diversification through export-oriented distribution systems and modern processing technologies, such as Individual Quick Frozen (IQF). This diversification effectively reduces market dependency, stabilizes long-term revenue generation, and strengthens the integration of local aquaculture production into national and international seafood value chains. Ultimately, these findings reinforce Widajanti's (10) argument that sustainable competitive advantage emerges when firms

systematically integrate resource efficiency, stakeholder engagement, innovation, and adaptive governance into coherent strategic systems.

Synthesis

Overall, the sustainability model at PT Graha Tambak Pinotu practically operationalizes the Triple Bottom Line framework (5) by synergistically integrating economic resilience, social empowerment, environmental stewardship, and strategic foresight into daily operations. This study extends previous aquaculture research by demonstrating that balanced multi-dimensional integration does not merely maintain operational stability and institutional capability, but directly drives the formation of a firm-level competitive advantage. From a macro perspective, these sustainability practices catalyze regional coastal development through employment generation and export-oriented production, creating a multiplier effect that strengthens the role of shrimp aquaculture as a strategic sector within Indonesia's blue economy agenda, thereby enhancing long-term regional competitiveness and investment attractiveness.

Competitive Advantage of PT Graha Tambak Pinotu in the Vannamei Shrimp Industry

The empirical findings indicate that the competitive advantage of PT Graha Tambak Pinotu is not derived from a single operational strength, but from the integration of geographic positioning, technological capability, human capital development, managerial efficiency, and export-oriented market strategy. This multidimensional configuration aligns with the conceptual understanding of competitive advantage as the firm's superior capacity in resources, capabilities, and performance relative to competitors (10). In this context, competitive superiority emerges from the alignment between sustainability-oriented practices and strategic operational management.

The analysis further demonstrates that the company's competitive advantage is closely linked to the research objective of examining how sustainability dimensions contribute to long-term business competitiveness. Unlike conventional aquaculture enterprises that primarily focus on production expansion, PT Graha Tambak Pinotu integrates sustainability-oriented management into strategic decision-making processes. As a result, sustainability practices become value-creating resources that strengthen operational efficiency, stakeholder legitimacy, and market adaptability. This finding supports the resource-based view that competitive advantage emerges from the firm's ability to manage valuable, rare, and difficult-to-replicate organizational capabilities.

Strategic Geographic Location

PT Graha Tambak Pinotu's location in the coastal area of Teluk Tomini, Pinotu Village, serves as a primary source of competitive strength due to its optimal biophysical characteristics. The ecosystem provides stable salinity, ideal temperature ranges, and moderate water currents that minimize physiological stress on shrimp stocks, thereby enhancing survival rates and growth consistency. From an operational perspective, this ecological suitability significantly optimizes feed efficiency, disease control, and overall production stability, aligning with findings that optimized management practices directly drive operational efficiency and aquaculture sustainability (16).

Logistically, the production site's proximity to major land transportation routes introduces a structural cost advantage by minimizing transit times for feed supply, seed distribution, and harvest delivery. This reduction in logistics costs optimizes operational expenditures, consistent with Porter's (17) cost leadership strategy. Furthermore, the location's isolation from heavy industrial pollution ensures uncontaminated surrounding waters, which safeguards environmental sustainability and guarantees high product quality capable of meeting strict domestic and export standards.

Ultimately, these findings demonstrate that geographic suitability transcends technical production performance to enhance economic efficiency across the broader aquaculture value chain. By mitigating environmental risks and reducing transportation overheads, the company secures superior production consistency and market competitiveness. Consequently, geographic advantage is reinterpreted not merely as a passive natural resource factor, but as an active strategic economic asset that strengthens the enterprise's competitive positioning and long-term sustainability in volatile seafood markets.

Technological Innovation and Production Efficiency

PT Graha Tambak Pinotu leverages technological adoption as a critical pillar of competitive advantage by implementing high-pressure aeration systems, structured feed management, probiotic-based water treatment, and real-time digital monitoring for temperature, pH, salinity, and ammonia. This integration of digital sensors enhances decision-making accuracy through the early detection of environmental deviations. By taking corrective measures before biological stress occurs, the company significantly reduces mortality rates and prevents large-scale production losses, which are vital for maintaining cost efficiency and operational resilience.

The application of probiotics over antibiotics reflects a strict adherence to biosecurity and sustainable aquaculture principles. This practice aligns directly with the Good Aquaculture Practices (CBIB) framework discussed by Salsabila and Zakiya (7), which emphasizes that standardized environmental management elevates both sustainability and market competitiveness. From a strategic perspective, this technological framework supports two of Porter's (17) generic strategies simultaneously: cost leadership (by reducing feed wastage and optimizing dissolved oxygen) and differentiation (by ensuring premium product quality and environmental compliance).

Furthermore, these digital monitoring systems strengthen production traceability, a strict requirement in international, export-oriented seafood supply chains. Documenting environmental parameters and operational practices builds transparency, which substantially increases global buyer confidence. Ultimately, these findings show that technological innovation serves as both an efficiency mechanism and a strategic differentiation instrument, marking a clear transition from conventional production-oriented farming toward knowledge-based, innovation-driven aquaculture systems.

Local Human Resource Development as Strategic Capital

Human capital development represents an important intangible asset contributing to the competitive advantage of PT Graha Tambak Pinotu. Most employees are recruited from local communities and receive structured technical training in pond preparation, feed management, disease monitoring, and digital production data interpretation. This approach reflects the concept of competitive advantage proposed by Widajanti (10), which emphasizes superiority in organizational capability and long-term performance sustainability. Continuous training programs improve technical competence, strengthen problem-solving capacity, and enhance organizational adaptability in responding to operational challenges within shrimp aquaculture production systems.

The company also implements internal mentoring systems in which senior technicians guide newly recruited employees to facilitate knowledge transfer and accelerate skill development. This mechanism supports the formation of a learning-oriented organizational culture while reducing performance variability across production cycles. From a socio-economic perspective, local workforce empowerment contributes to regional economic circulation through employment opportunities and stable household income within coastal communities. Similar to previous sustainability studies (18, 19), community-based human capital development strengthens social legitimacy and institutional acceptance. In addition, the present findings indicate that workforce empowerment simultaneously functions as a strategic resource that supports organizational stability, employee retention, and long-term business competitiveness.

Managerial Efficiency and Adaptive Governance

Managerial efficiency and adaptive governance implemented by PT Graha Tambak Pinotu demonstrate an important role in maintaining operational sustainability amid market uncertainty and fluctuating production costs. Managerial competence functions as an institutional foundation that supports the company's competitive advantage. The company applies structured planning in each production cycle, including cost allocation, feed scheduling, risk assessment, and post-harvest evaluation. Routine evaluations conducted at the end of each cycle create an adaptive feedback mechanism in which operational constraints are collectively analyzed to formulate improvement strategies for subsequent production periods. This iterative learning process strengthens the company's dynamic capability in responding to changing environmental and market conditions.

The implementation of digital financial recording systems also contributes significantly to administrative transparency and decision-making efficiency. Detailed financial monitoring enables management to identify irregularities, adjust budget allocations, and anticipate fluctuations in feed prices and export demand. Efficient financial governance therefore enhances the responsiveness of the company to economic uncertainty within aquaculture commodity markets. In a broader context, adaptive managerial capability becomes increasingly important for aquaculture enterprises operating in environmentally sensitive coastal areas and highly competitive export-oriented industries.

In addition, effective coordination between production teams and administrative units improves organizational coherence and operational reliability. Data integration across departments ensures that managerial decisions are evidence-based and synchronized across operational sectors, thereby reducing inefficiency and strengthening competitive positioning. From a theoretical perspective, this managerial structure reflects Porter's strategic coherence principle (17), which emphasizes that consistency between operational management and market positioning contributes significantly to sustainable organizational performance.

Market Expansion and Export Orientation

Market diversification represents an important dimension of competitive advantage for PT Graha Tambak Pinotu. The company has expanded its distribution beyond local markets toward national and international trade networks, requiring compliance with strict export standards related to product quality, documentation, cold-chain logistics, and traceability systems. To support export readiness, the company implements Individual Quick Frozen (IQF) technology, which rapidly freezes shrimp at temperatures around −20°C to preserve texture, nutritional value, and microbiological quality. This process minimizes cellular damage and drip loss, thereby maintaining product quality and extending shelf life during distribution. Previous studies have shown that IQF technology contributes significantly to quality retention and strengthens compliance with international seafood export standards (20). Furthermore, the adoption of advanced freezing technology enables the company to meet increasingly stringent buyer requirements in global seafood markets, particularly regarding product consistency, safety, and quality assurance throughout the supply chain.

The implementation of IQF technology, combined with consistent cold-chain management, strengthens the company's differentiation strategy in highly competitive seafood markets. Export-oriented markets generally provide higher price margins and more stable demand compared to local markets, thereby reducing dependency on a single buyer segment and minimizing market risks. This condition reflects Porter's focus strategy, where firms target specific market segments that prioritize standardized and premium-quality products. In addition, the company actively participates in export training programs and trade partnership networks to improve institutional readiness and expand market access through certification compliance and strategic collaboration. These initiatives not only enhance the company's operational capabilities but also facilitate knowledge transfer, market intelligence acquisition, and stronger relationships with international stakeholders, all of which are essential for sustaining export performance.

The expansion toward export markets also demonstrates the increasing integration of Indonesian shrimp aquaculture into global seafood trade systems. International buyers increasingly demand product traceability, food safety assurance, and environmental compliance, encouraging aquaculture enterprises to adopt sustainability-oriented operational standards. Consequently, sustainability functions not only as an

ethical commitment but also as a strategic requirement for accessing higher-value international markets. These findings indicate that sustainability implementation and competitive advantage are mutually reinforcing elements that support the long-term resilience and market competitiveness of modern aquaculture industries. The alignment between sustainability practices and export requirements creates additional opportunities for long-term business growth, strengthens corporate reputation, and enhances the company's ability to respond to evolving regulatory and consumer expectations in international markets.

Synthesis: Competitive Advantage as an Outcome of Integrated Sustainability

The findings of this study demonstrate that competitive advantage at PT Graha Tambak Pinotu is closely associated with the integration of sustainability-oriented practices across multiple operational dimensions. Geographic suitability supports ecological stability, technological innovation improves production efficiency and product quality, human resource development enhances adaptive capacity, and managerial governance strengthens operational effectiveness. In addition, market diversification and export orientation contribute to economic resilience by reducing dependency on local markets and increasing access to higher-value trade networks. This integrated management configuration supports the theoretical perspective that sustainable resource management can function as a strategic asset capable of strengthening long-term competitiveness (5, 10).

From a broader perspective, the implementation of sustainability principles also contributes to regional economic development through employment generation, increased export potential, and strengthened coastal economic activities. These findings indicate that sustainability should not be viewed solely as an environmental or regulatory obligation, but also as a long-term economic strategy that enhances competitiveness within Indonesia's growing blue economy sector. Overall, PT Graha Tambak Pinotu demonstrates that modern aquaculture competitiveness increasingly depends on the ability to integrate environmental responsibility, technological capability, adaptive governance, and social legitimacy into a coherent and sustainable management framework.

Conclusion

This study advances the sustainable aquaculture literature by providing a novel theoretical synthesis that bridges the *Triple Bottom Line* (TBL) framework with the *Resource-Based View* (RBV) of competitive advantage within emerging coastal economies. The empirical evidence demonstrates that sustainability practices at PT Graha Tambak Pinotu are not merely operational compliance mechanisms, but are institutionalized as strategic, intangible assets that generate sustainable competitive superiority. By systematically aligning economic productivity, localized social empowerment, and biosecurity-oriented environmental stewardship into a coherent strategic governance structure, this research conceptually proves that sustainability and firm competitiveness are mutually reinforcing strategic dimensions. This integration redefines conventional aquaculture paradigms, shifting from short-term production intensification toward a knowledge-driven, resilient economic framework capable of navigating global market fluctuations and environmental vulnerabilities.

The primary scientific contribution of this research lies in its empirical validation of how localized environmental stewardship and participatory stakeholder governance directly transform into market differentiation and operational cost leadership. Strategically, the institutionalization of systematic wastewater infrastructures and localized human capital deployment serves as an empirical blueprint for executing the "*blue economy*" agenda in developing maritime nations. The study also demonstrates that community-based resource management and environmentally responsible production practices can create measurable business value by strengthening stakeholder trust, improving operational efficiency, and supporting access to premium market segments. While this study is limited by its single case-study boundary and qualitative interpretive nature, it lays a foundational conceptual framework for future inquiry. Subsequent research should deploy quantitative structural equation modeling (SEM), comparative multi-site frameworks, and longitudinal designs to empirically measure the direct causal trade-offs between quantitative sustainability metrics, real-time biomass performance, and long-term financial competitive advantage across global aquaculture networks.

Declaration

Author Information

Aris Jumadil
Department of Sharia Economics, Faculty of Economics and Islamic Business, State Islamic University Datokarama Palu, Palu - 94221, Indonesia.
Contribution: Data Curation, Formal analysis, Visualization, Writing - Original Draft, Writing - Review & Editing.

Sitti Aisya
*Corresponding author
Department of Sharia Economics, Faculty of Economics and Islamic Business, State Islamic University Datokarama Palu, Palu - 94221, Indonesia.
Contribution: Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Writing - Review & Editing.

Ferdiawan Ferdiawan
Department of Sharia Economics, Faculty of Economics and Islamic Business, State Islamic University Datokarama Palu, Palu - 94221, Indonesia.
Contribution: Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Writing - Review & Editing.

Conflict of Interest

The authors declare no conflicting interest.

Data Availability

All data generated or analyzed during this study are

included in this published article [and its supplementary information files]. Additional datasets are available in [repository name] at [DOI or link].

Ethics Statement
Ethical approval was not required for this study.

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