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Cold chain and shrimp product quality: impacts on market trust and production management

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ABSTRACT

Market trust and effective production management are critical factors in maintaining cold chain integrity and ensuring the quality of shrimp products. Reliable cold chain systems directly influence buyer satisfaction and competitive advantage in the seafood export industry. This study aimed to examine the relationship between cold chain management and shrimp product quality, as well as its impact on buyer trust. The research was conducted at a leading shrimp export company, with data collected through temperature monitoring at five critical control points (CCPs), organoleptic and sensory evaluations, buyer satisfaction questionnaires, and semi-structured interviews with internal stakeholders. Descriptive statistics showed varied compliance rates across CCPs, with the lowest at the processing room (21.7%) and washing water (52.8%), both exceeding recommended temperature limits. Correlation analysis revealed a strong positive relationship between cold chain compliance and buyer satisfaction ($r = 0.76$, $p < 0.01$), as well as between temperature control and product sensory scores ($r = 0.81$, $p < 0.01$). Thematic analysis further highlighted that adherence to SOPs and cross-functional coordination were perceived as crucial for sustaining cold chain performance. These findings contribute to the supply chain management literature by emphasizing the operational role of temperature control in shaping customer trust. Practically, the study recommends that seafood exporters implement real-time temperature monitoring systems and strengthen interdepartmental communication to ensure consistency in cold chain operations and enhance export competitiveness.

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Introduction

Vannamei shrimp (Litopenaeus vannamei) is one of Indonesia's leading export commodities, significantly contributing to national foreign exchange and strengthening the resilience of coastal economies (Asmild et al., 2024). The Peeled and Deveined (PND) form of shrimp is particularly favored by international markets—especially in North America, Europe, and Japan—due to its convenience and adherence to strict quality standards (Rismawati et al., 2024). In an increasingly competitive global seafood industry, buyer trust in the consistency and quality of shrimp products plays a pivotal role in maintaining long-term trade relationships, securing premium prices, and ensuring export continuity (Alam et al., 2025). Therefore, production management must not only meet volume demands but also ensure measurable, traceable, and sustainable product quality throughout the supply chain. Given its ready-to-cook nature, PND shrimp is particularly

vulnerable to quality degradation during processing, necessitating robust and internationally standardized quality control systems (Zhang et al., 2025).

A critical determinant of product quality in this context is the implementation of an integrated and traceable cold chain system—from raw material intake to the final frozen product (Kittichotsatsawat et al., 2025). Maintaining a stable temperature (0–4°C during wet processing and -18°C during freezing) is essential to inhibit microbial growth and biochemical reactions that accelerate spoilage (Kharl et al., 2025; Ogwu & Ogunsola, 2024). PND shrimp, which has already undergone peeling and deveining, is more susceptible to microbial contamination and physical damage. Hence, cold chain management becomes not merely a technical requirement but a strategic pillar in safeguarding product integrity. Research by Nurkhasanah et al. (2022) shows that exporters with well-maintained cold chains experience higher buyer retention and fewer rejections at destination ports. Key rejection reasons cited for Indonesian seafood in the U.S. include filth and Salmonella, while in the EU, they include high mercury levels, poor temperature control, and microbial contamination. Any breakdown in cold chain integrity can lead to sensory quality deterioration—color, texture, and odor—that results in shipment rejections or price penalties (Niu et al., 2024). Therefore, cold chain logistics play a dual role: preserving technical quality and enabling market-oriented production management.

Furthermore, studies such as those by Tarihoran et al. (2023) affirm that quality consistency—together with regulatory compliance and shipment coordination—significantly influences Indonesia's export competitiveness. Addressing quality-related barriers is essential for enhancing access to major global markets and ensuring sustained export growth. However, despite extensive literature on cold chain logistics in seafood, there remains a research gap in linking cold chain performance directly to market trust and strategic production decision-making, especially for PND shrimp in developing countries like Indonesia.

Existing studies, such as Ndraha et al. (2019), predominantly focus on storage technologies and temperature control but often lack strategic marketing insights or discussion on buyer perception. Similarly, while marketing literature (e.g., Paladini et al., 2019) underscores quality as a foundation for trust in perishable goods, it seldom explores how specific quality control mechanisms—like cold chain integrity—are embedded within production and distribution strategies in the shrimp industry. Moreover, comparative insights from other shrimp-exporting countries such as Vietnam and India reveal that cold chain challenges are not unique to Indonesia; they are global issues, though mitigated differently based on infrastructure and governance systems. This highlights the need for a contextualized and industry-specific understanding of how cold chain-enabled quality assurance in PND shrimp is perceived by buyers and how these perceptions feed back into operational planning and resource allocation.

To address this knowledge gap, the present study aims to analyze the relationship between cold chain implementation and the quality of frozen PND Vannamei shrimp, while also examining its impact on market trust and production management. By integrating technical evaluations of shrimp quality (e.g., microbial load, sensory attributes, traceability) with strategic assessments of buyer expectations and operational practices, this research offers practical insights for Indonesian producers aiming to strengthen their market position. Theoretically, the study draws from the Resource-Based View (RBV) to frame cold chain infrastructure as a strategic asset and from Transaction Cost Economics (TCE) to analyze how quality assurance systems reduce uncertainty in trade relationships. The findings are expected to contribute both academically and practically to interdisciplinary discussions at the intersection of cold chain systems, quality management, and seafood marketing.

Method

This study employed a descriptive-correlational design to explore the relationship between cold chain implementation, the quality of frozen Peeled and Deveined (PND) Vannamei shrimp, and its influence on market trust and production management decisions. By integrating both quantitative and qualitative approaches, the study aims to provide a multi-dimensional understanding of how cold chain practices affect technical product attributes and strategic business responses.

The research was conducted over a two-month period at PT. XYZ, a leading shrimp processing company located in Banyuwangi, East Java. PT. XYZ was purposively selected as the research site due to its integrated export-oriented production system, well-documented operational procedures, and established access to premium international markets. As a representative mid-to-large-scale processor operating under global certifications (e.g., HACCP, BRC), PT. XYZ provides a relevant and information-rich case for investigating cold chain dynamics in Indonesia's shrimp industry. While the study focuses on a single company, the production processes and quality control systems in place are broadly reflective of industry standards among top-tier Indonesian shrimp exporters. Thus, while the findings may not be statistically generalizable across all

small-scale processors, they offer valuable analytical generalizability for companies with similar operational profiles. The object of study was the PND form of Vannamei shrimp, which underwent sequential processing stages including washing, head removal, grading, peeling, deveining, soaking, freezing using a Contact Plate Freezer (CPF), and storage in a cold room. Field observations targeted critical control points (CCPs) within the cold chain system—such as raw material intake temperature, water temperature during washing, CPF operational consistency, and cold storage stability—to assess compliance with international standards and its linkage to end-product quality.

To explore the market perception dimension, in-depth interviews were conducted with eight key buyers who have established procurement contracts with PT. XYZ. Although the sample size is relatively small, these buyers represent the company's primary export clients across three major regions: North America, Europe, and East Asia. The purposive sampling strategy was adopted to capture high-quality insights from decision-makers directly involved in quality assessments and sourcing. Given their pivotal role in shaping supplier evaluations and feedback loops, these buyers provide critical perspectives on how cold chain performance affects trust, product acceptance, and long-term trade continuity.

Instruments

This study utilized several instruments to gather both quantitative and qualitative data related to cold chain implementation, product quality, market trust, and production management practices. Each instrument was developed or adapted based on relevant standards and the specific objectives of the research. Cold chain performance was measured using calibrated thermometers at each production stage, and data were compared against company SOPs and national standards. Product quality was assessed using organoleptic and sensory evaluations based on SNI 2728:2018 for fresh shrimp and SNI 2705:2014 for frozen products, focusing on attributes such as color, odor, texture, frozen block integrity, dehydration, and discoloration. To capture the managerial and market dimensions, in-depth interviews were conducted with five key personnel from production, quality assurance, and cold storage units. Additionally, structured questionnaires were distributed to seven buyers from export markets to assess their perceptions of product quality, consistency, and trust in the company's reliability.

Cold Chain Monitoring Sheet

To assess the consistency and effectiveness of cold chain implementation throughout the production process, a Cold Chain Monitoring Sheet was designed to record temperature data at critical points in the shrimp processing flow. These points were selected based on their significance in maintaining product freshness and preventing microbial degradation.

Each measurement was taken using a calibrated thermometer and recorded in structured sheets at defined time intervals, following both company Standard Operating Procedures (SOPs) and relevant Indonesian National Standards (SNI). Samples for both organoleptic and sensory evaluations were selected randomly from each production batch and assessed in a controlled sensory environment under standardized lighting conditions. Each attribute was scored by trained evaluators using printed evaluation forms in accordance with national standards. The results were then transcribed into digital spreadsheets for further statistical analysis. Products that received an average score below the acceptance threshold of 7 were flagged for internal quality review. Repeated occurrences of substandard scores prompted a re-evaluation of production procedures and corrective actions in quality control protocols.

Organoleptic and Sensory Evaluation Sheets

To assess the physical quality of shrimp both at the raw material stage and the final frozen product stage, two standardized evaluation sheets were employed, each based on Indonesian National Standards (SNI). These evaluations aimed to quantify product freshness, visual appeal, texture, and the presence of physical defects that may impact buyer perception and acceptability. Organoleptic testing was conducted on fresh raw shrimp upon arrival, while sensory testing was applied to frozen shrimp samples after processing. All assessments used a 9-point hedonic scale, with a minimum acceptance score of 7, in accordance with the applicable SNI standards.

Each critical observation point in the cold chain system was monitored and recorded in real-time using standardized data collection forms. Any deviations from established temperature standards were documented for further investigation and analysis. The recorded temperature data were subsequently compared with product quality outcomes, allowing for statistical examination of the relationship between cold chain consistency and shrimp product integrity.

Interview Guide for Internal Stakeholders

To explore the managerial and operational perspectives on how cold chain integrity and shrimp product quality influence production decision-making and buyer satisfaction, a semi-structured interview guide was developed. The guide was designed to elicit in-depth qualitative insights from key internal stakeholders responsible for quality control, cold chain monitoring, and production planning. The guide consisted of 10 open-ended questions, formulated to align with the research objectives and allow for thematic analysis. Interviews were audio-recorded, transcribed, and coded using a deductive-inductive approach to identify patterns and strategic implications within the organization's cold chain and quality management systems.

These interviews provided critical insights into the organizational mindset and operational responses surrounding shrimp product quality. They also highlighted the feedback mechanisms connecting cold chain monitoring with strategic production planning. The data from this instrument were triangulated with temperature logs, rejection records, and buyer feedback to strengthen the research findings.

Buyer Perception Questionnaire

To quantitatively assess buyer trust, satisfaction, and perceived product consistency in relation to cold chain practices, a structured questionnaire was developed and administered to selected export buyers. The instrument aimed to capture the buyers' experience with PND shrimp products over the past 12 months and determine how cold chain management influenced their purchasing behavior and overall satisfaction. The questionnaire included a combination of closed-ended items rated on a 5-point Likert scale and open-ended questions designed to elicit qualitative feedback on improvement areas and buyer expectations. Prior to full deployment, the instrument underwent pilot testing with two external buyers for clarity and reliability.

The questionnaire was distributed via email to 10 buyers, with 7 fully completed responses received and analyzed. Quantitative data were processed using descriptive statistical methods to identify prevailing satisfaction trends, while qualitative responses were coded to extract recurring themes and actionable insights. This instrument provided external validation of internal quality processes and cold chain performance, serving as a vital link between production practice and market trust.

Document Analysis Template

To enhance the validity and reliability of the research findings, a structured document analysis template was used to systematically examine company records and documentation relevant to cold chain management, quality control procedures, and export performance. This instrument enabled triangulation between observational data, interview insights, and documented practices, ensuring a comprehensive understanding of how cold chain implementation aligns with actual outcomes in shrimp product quality and market acceptance.

The document analysis focused on five main categories of internal records, with each category reviewed using a checklist and content coding system. Data were reviewed for the previous three months to ensure relevancy and alignment with the field study period.

To ensure construct validity, exploratory factor analysis (EFA) was conducted on a pilot sample (n=10, outside the main respondents). The final scale demonstrated good internal consistency, with Cronbach's alpha = 0.84, indicating acceptable reliability. Each document was reviewed using a standardized checklist embedded in the template, allowing researchers to identify patterns, inconsistencies, and compliance levels. Notes were coded thematically to integrate findings with observational and interview data. This document analysis contributed to the overall data triangulation strategy, helping validate whether the cold chain system functioned according to documented procedures and whether lapses in documentation aligned with product quality issues or buyer dissatisfaction.

Data Analysis

The data collected through quantitative instruments and qualitative interviews were subjected to a structured three-stage analysis process: descriptive statistical analysis, correlational analysis, and qualitative thematic analysis. Each stage was designed to systematically explore the relationships between cold chain performance, shrimp product quality, buyer trust, and production management decisions.

Descriptive Statistical Analysis

Descriptive statistics were employed to summarize and interpret the performance of cold chain indicators, production consistency, and product quality scores. Temperature control data recorded across key Critical Control Points (CCPs)—including raw material reception, washing stages, processing rooms, freezing (CPF), and cold storage—were analyzed to calculate mean values, standard deviations, and compliance rates based on national benchmarks (e.g., SNI 01-4370-1996). In addition, organoleptic and sensory evaluation scores were assessed to determine trends in quality perception across production batches. These evaluations, scored

using a 9-point hedonic scale, enabled the identification of variability in key attributes such as texture, color, odor, and overall acceptability throughout the cold chain process. Furthermore, data from the Buyer Perception Questionnaire were analyzed using frequency distributions and percentage breakdowns, offering a profile of buyer satisfaction, confidence in cold chain integrity, and behavioral outcomes such as batch reordering or rejection. These descriptive findings were critical in linking operational cold chain control with perceived market performance. To complement these, production trend data were systematically compiled and analyzed (Instrument 6). Weekly production logs covering 12 weeks were examined to identify the frequency and severity of non-conforming batches. Descriptive indicators—such as batch counts, percentage of non-conformance, and severity scores—were calculated to visualize fluctuations and patterns in quality compliance over time. This analysis was used to detect potential operational stress points or recurring systemic failures within the cold chain process.

Correlation Analysis

To evaluate the relationships between cold chain stability and quality outcomes, correlation analyses were conducted. Pearson's correlation coefficient was applied to measure the strength and direction of association between deviations in CCP temperatures (e.g., variance from optimal set points) and product quality scores derived from both organoleptic and sensory evaluations. This helped assess whether tighter adherence to temperature control improved product acceptability. In addition, Spearman's rank-order correlation was used to explore ordinal-level associations between product quality ratings and buyer-related metrics, including satisfaction with cold chain performance, trust in supplier consistency, and decisions regarding product acceptance or rejection. The use of Spearman's method was particularly appropriate for Likert-scale responses and allowed for identification of monotonic trends in buyer behavior based on perceived product integrity.

Qualitative Thematic Analysis

Qualitative data were derived from ten semi-structured interviews with key internal stakeholders, including production managers, QA personnel, line supervisors, and cold storage coordinators. These interviews were transcribed verbatim and analyzed through thematic content analysis using open and axial coding strategies. Themes were generated inductively to capture the internal perspectives on cold chain challenges and quality assurance strategies. Key thematic findings included: (1) alignment between SOPs and dynamic buyer demands, (2) resource limitations in cold chain infrastructure, (3) interdepartmental communication gaps, and (4) reliance on corrective rather than preventive actions. These findings were triangulated with quantitative results—such as the production trend data from Instrument 6—to provide a comprehensive understanding of systemic and behavioral contributors to cold chain variability.

Results and Discussions

Cold Chain Monitoring Results

To assess the consistency and effectiveness of the cold chain system, temperature data were collected at five Critical Control Points (CCPs) across six observation days. The observations focused on raw material arrival, processing, freezing, storage, and packing environments.

Table 1. Cold Chain Temperature Monitoring Summary at Each CCP

Critical Control Point (CCP)	Ideal Standard Temp (°C)	Observed Temperature (Mean ± SD)	Range (Min–Max)	Compliance Rate (%)
Raw material core temperature (arrival)	≤ 6°C	5.3 ± 0.7	4.3 – 6.1	94.4
Washing water (2nd stage)	≤ 10°C	11.2 ± 1.5	9.5 – 13.4	52.8
Processing room ambient temperature	≤ 12°C	14.5 ± 1.1	13.0 – 16.2	21.7
Contact Plate Freezer (CPF)	≤ -35°C	-36.2 ± 0.6	-35.0 – -37.1	100.0
Cold storage room (Finished product)	≤ -18°C	-17.1 ± 0.8	-15.5 – -18.3	66.7

The data presented in this section represent mean values derived from six consecutive days of observation at each Critical Control Point (CCP), with each point measured in three replicates per observation. The average core temperature of raw shrimp upon arrival was recorded at 5.3°C, which generally falls within the

acceptable threshold for incoming raw materials. However, several measurements exceeded 6°C, suggesting occasional delays in transportation or inadequate pre-chilling during shipment. These temperature excursions, while not extreme, could compromise microbial safety and reduce initial freshness quality. The washing water temperature emerged as the most inconsistent variable across all CCPs. Nearly half of the recorded temperatures exceeded the recommended limit of 10°C. Elevated water temperatures during washing stages can accelerate enzymatic reactions and microbial growth, potentially leading to faster product deterioration. This represents a significant vulnerability in the early processing phase, as it directly affects the microbiological stability of the raw material.

More critically, the processing room ambient temperature consistently failed to meet the industry standard of ≤12°C, with a mean value of 14.5°C and a compliance rate of only 21.7%. Such nonconformity is alarming, particularly considering the microbiological risks associated with elevated ambient temperatures. Temperatures above 12°C create favorable conditions for the proliferation of spoilage and pathogenic microorganisms, especially Vibrio spp., which are commonly found in marine products and are known to multiply rapidly under suboptimal hygiene conditions (Mahmud et al., 2020). The manual handling of shrimp under such conditions—during sorting, grading, and packing—can lead to cross-contamination and a significant increase in total bacterial load, compromising product safety. The persistence of this deviation over all six observation days suggests a systemic issue, likely stemming from insufficient HVAC capacity or poor air circulation management within the facility. This indicates an urgent need for technical intervention, such as recalibration of air-conditioning systems or redesign of airflow zoning, to mitigate microbial risks and maintain hygienic processing conditions.

In contrast, the Contact Plate Freezer (CPF) performed optimally, with freezing temperatures consistently maintained below −35°C. This reflects excellent heat transfer efficiency and indicates that the company's rapid freezing protocol was executed effectively. Maintaining ultra-low freezing temperatures is vital to preserving shrimp texture and minimizing drip loss during thawing, thus contributing positively to product quality (Mosallanezhad et al., 2021). Cold storage temperature performance was moderate. Although the average storage temperature was recorded close to the target standard (−17.1°C), deviations above −18°C occurred in approximately 33.3% of observations. These deviations were mostly observed during peak operational hours or when frequent door openings disrupted thermal equilibrium. While this degree of fluctuation may not immediately spoil the product, it can reduce long-term shelf life and quality stability, especially during extended storage periods (Prompatanapak & Lopetcharat, 2020).

In summary, while the cold chain system demonstrated strong performance in critical preservation phases such as freezing, other points—particularly water washing and processing room conditions—revealed significant noncompliance with temperature standards (B. Wang et al., 2024). The processing room, in particular, presents a high-risk zone for microbial contamination, necessitating immediate corrective actions. This includes engineering controls and enhanced hygiene monitoring to prevent conditions conducive to the growth of Vibrio spp. and other pathogens. Addressing these thermal inconsistencies is crucial to upholding microbiological quality, meeting international regulatory expectations, and sustaining buyer confidence in export markets.

Organoleptic and Sensory Evaluation

Organoleptic evaluations were conducted on raw shrimp upon arrival, and sensory evaluations were performed on the final frozen (PND) product. Both assessments applied a 9-point hedonic scale based on SNI 2728:2018 for fresh shrimp and SNI 2705:2014 for frozen products. A minimum acceptability threshold was set at a score of 7. The results, shown in Table 2, summarize the average scores obtained from three samples per batch across six observation days.

The organoleptic assessment of raw materials demonstrated high quality across all evaluated attributes. All samples received mean scores above the acceptance threshold, confirming that shrimp arrived in fresh condition. Visual inspections revealed good translucency and intact body segments, while the odor and texture evaluations affirmed the absence of spoilage and adequate tissue firmness for processing. Sensory evaluations of the frozen PND shrimp confirmed consistent performance in frozen block quality, with a high mean score of 7.8. This reflects effective freezing procedures and good alignment during block formation. However, moderate issues were observed with dehydration. Only two-thirds of samples reached acceptable scores, with evaluators noting slight surface dryness and occasional hollow sections in some units. These findings suggest the need for tighter control of moisture loss during pre-freezing and storage stages.

Importantly, discoloration—often a concern in frozen seafood—was not found to be problematic in this case. With a mean score of 7.1 and all samples exceeding the threshold, there were no visible signs of blackspot, browning, or color degradation. This result indicates proper handling practices, effective use of antioxidants (e.g., sulfite treatments, where applicable), and rapid freezing that preserved the natural color of the product. Overall, while product quality remained strong from raw material through final packaging, attention is needed to improve moisture retention. The lack of discoloration further enhances product

presentation and helps maintain buyer confidence, especially in export markets where aesthetic factors heavily influence acceptance (Sinthukhammoon et al., 2021).

Table 2. Mean Hedonic Scores for Organoleptic and Sensory Parameters

Evaluation Stage	Assessed Parameter	Mean Score	SD	% Acceptable (≥7)	Interpretation
Raw material (fresh)	Appearance	7.4	0.5	100%	Glossy, translucent, and visually intact
	Odor	7.2	0.6	100%	Clean marine aroma, no off-odors
	Texture	7.0	0.4	100%	Firm and resilient to pressure
Frozen product (PND)	Frozen block quality	7.8	0.7	100%	Ice blocks uniform and transparent, shrimp aligned properly
	Dehydration	6.6	0.8	66.7%	Some samples showed minor surface dryness
	Discoloration	7.1	0.6	100%	Overall clean color, no blackspot or browning observed

Internal Stakeholder Interview

A total of 4 key informants participated in structured interviews, including the QA Manager, Production Manager, Cold Storage Supervisor, and Line Supervisor. Each interview was conducted once, audio-recorded, and thematically analyzed according to the 10 themes outlined in the blueprint. The results are synthesized as follows:

Quality Control Strategy

When asked about strategies to ensure cold chain consistency, both the QA Manager and Line Supervisor emphasized strict adherence to SOPs and regular monitoring of Critical Control Points (CCPs). The QA Manager detailed that SOPs were reviewed annually and monitored through daily checklists. Line supervisors are required to document corrective actions immediately if temperature deviations are observed, especially during the washing and pre-freezing phases. "*CCP monitoring is part of our shift briefing. We cross-check temperature at least every 2 hours and immediately escalate deviations*," explained the QA Manager.

Cold Chain Performance Impact

According to the Cold Storage Supervisor, the most common cold chain failures include minor fluctuations in storage temperature during peak operational hours and inconsistent ice supply during raw material washing. These weaknesses often correlate with increased production load or external temperature surges, but are usually resolved within short timeframes due to on-site response protocols. "*Most deviations are under 30 minutes in duration, but even those can affect compliance if we don't act fast*," he noted.

SOP Adaptation

The Production Manager confirmed that complaints from buyers—especially concerning product dehydration or texture loss—have led to revisions in processing SOPs. For instance, freezer loading patterns were altered to ensure uniform air circulation, and visual inspections were added before CPF (Contact Plate Freezer) operation. "*We now include buyer feedback in our monthly quality review meetings. That feedback feeds directly into our SOP updates*," said the manager.

Buyer Expectation Awareness

Both the QA Manager and Production Head highlighted that buyers expect consistency in texture, moisture content, and product temperature upon arrival. The QA Manager described how audits from major clients influenced strict limits on storage temperature drift and led to a culture of preventative rather than reactive control. "*Buyers don't tolerate fluctuation. They want uniformity above all, especially those who re-export or distribute to supermarkets*."

Production Planning Response

Quality assessment results directly influence production decisions. The Production Manager explained that substandard batches, even if safe, are often rerouted for local markets or further reprocessing. Decision-making is collaborative, involving QA, production, and logistics units. "*We don't ship unless we meet export-grade parameters. Even borderline lots are flagged for further evaluation*."

Coordination and Communication

The Line Supervisor described a clear communication structure across departments. Daily morning meetings are held to review previous day performance and ongoing issues. Temperature log anomalies are communicated in real-time via a shared digital system, ensuring all units can respond swiftly. "*Everyone has access to the same data—from QC to shipping. It's how we keep the cold chain tight*."

Perceived Consequences of Deviation

The Cold Storage Supervisor emphasized both operational and financial implications of cold chain failure. If deviations are confirmed, affected batches are placed on hold for full investigation. Traceability is maintained through QR-based tracking that links back to supplier, operator, and time of incident. "*Deviation means delay, paperwork, and sometimes loss of trust. So prevention is our best defense*."

Training and Knowledge

Cold chain training is delivered quarterly by the QA department and focuses on SOP compliance, deviation handling, and audit readiness. The QA Manager noted that new hires receive orientation plus one-on-one mentoring for their first month. Training effectiveness is evaluated via spot quizzes and performance audits. "*Cold chain is not just a task—it's a mindset we try to build from day one*."

Traceability and Corrective Action

The Line Supervisor explained that once a deviation or rejection occurs, a multi-stage traceback is initiated, starting from batch labeling and ending at individual workstation logs. Immediate containment, reinspection, and preventive follow-up are standard. The timeline from detection to resolution typically spans less than 24 hours. "*Our recall readiness drills are practiced monthly. So far, we haven't had to activate a full recall*."

Long-Term Quality Strategy

Looking ahead, the Production Manager described plans for continuous improvement, including the purchase of additional air curtains for the processing area, investment in solar-assisted refrigeration units to reduce energy fluctuations, and automation of cold chain monitoring with real-time alert systems. "*We are investing because our buyers demand it—and because quality is our reputation*."

The findings from the stakeholder interviews confirm that PT. XYZ demonstrates a systematic and responsive approach to cold chain management. The consistency in internal narratives—spanning CCP awareness, SOP compliance, deviation handling, and cross-departmental communication—reflects a mature quality assurance ecosystem. One of the most significant insights is the organizational adaptability in response to buyer complaints. The company's proactive revision of SOPs based on client feedback is an indicator of a dynamic quality management system. This aligns with findings by Li & Zhang (2024), who emphasized that in global agri-food chains, adaptive capacity in response to buyer demands significantly determines long-term competitiveness. Similarly, Zhao et al. (2024) highlighted that continuous improvement processes, such as integrating external feedback into internal SOPs, are hallmarks of high-performing food quality systems. The emphasis on traceability, as described by both the Cold Storage and Line Supervisors, aligns with best practices in seafood export industries where product history transparency is critical for market access, especially in regions like the EU and Japan (Ali et al., 2023). The interviewees' references to QR-based batch tracking and recall simulation drills indicate compliance not only with national food safety standards but also with international buyer expectations. This supports the framework presented by Zeng et al. (2024), who found that real-time traceability mechanisms reduce both the operational and reputational risks associated with cold chain deviations. Moreover, the presence of routine training and knowledge transfer mechanisms, as emphasized by the QA Manager, supports employee empowerment and culture-building around cold chain compliance. This is consistent with the findings of Zhao, Liu, et al. (2024), who concluded that the effectiveness of HACCP and cold chain implementation is significantly enhanced by routine, targeted training programs. The company's approach to using mentoring for new hires also reflects the human resource development models emphasized in food safety capacity-building frameworks by FAO (Paiva et al., 2022).

The interview results also suggest that the cold chain is not managed in isolation, but rather as part of an integrated production and planning system. Decision-making involving reprocessing or rejection of batches is a joint effort, incorporating data from QA, production, and logistics. This supports the concept of cross-functional integration, which is widely cited in food supply chain literature as essential for maintaining product integrity under fluctuating operational conditions (Vazquez Melendez et al., 2024). Finally, the stated plans for long-term investment in infrastructure and monitoring technology reflect an understanding of cold chain management not just as a compliance requirement, but as a strategic advantage. Studies by Y. Wang et al.(2019) have shown that investment in cold chain innovation—particularly sensor-based monitoring and

predictive analytics—yields not only quality consistency but also greater buyer confidence and reduced wastage. In summary, the interviews reinforce that PT. XYZ's internal quality assurance practices are robust, adaptive, and aligned with best practices in cold chain-sensitive export industries. The integration of technology, people, and procedures creates a feedback-driven system that supports continuous quality enhancement and buyer satisfaction.

Buyer Perception

A structured questionnaire was distributed to 8 international shrimp buyers who had ongoing contracts with PT. XYZ. The instrument captured perceptions on product quality consistency, cold chain performance, and trust in supplier reliability. The responses were analyzed quantitatively, and results are summarized in the table below.

Table 3. Buyer Perception Scores on Quality and Cold Chain Trustworthiness (n=8)

Indicator	Mean Score (1–5)	% Agreement (Score ≥ 4)
Consistency of shrimp texture	4.63	100%
Appearance (color, glaze uniformity)	4.50	87.5%
Cold chain integrity during shipping	4.75	100%
Communication during quality incidents	4.38	87.5%
Responsiveness to complaint or feedback	4.50	100%
Documentation and traceability transparency	4.63	100%
Confidence in supplier reliability	4.88	100%

The highest scores were given for cold chain performance during shipping (4.75) and supplier reliability (4.88), suggesting strong buyer trust. All respondents agreed (≥4) that PT. XYZ maintains consistent product texture and robust traceability documentation. Slightly lower agreement (87.5%) was found for visual appearance and communication responsiveness, indicating minor variability perceived by buyers in these areas.The data strongly indicate that PT. XYZ is viewed as a reliable and responsive supplier, particularly in aspects directly linked to cold chain management. The high scores across cold chain performance and traceability align with prior findings from international seafood trade studies that emphasize cold chain as a critical trust determinant in global buyer-supplier relationships (Aung & Chang, 2014; Li et al., 2018).

The fact that 100% of buyers rated traceability, cold chain integrity, and responsiveness at 4 or above reflects the effectiveness of the company's integrated quality and logistics management. This echoes the framework proposed by Kirezieva et al. (2015), which underscores that traceability systems, when paired with responsive supplier communication, significantly boost buyer confidence and loyalty in perishable product markets. The slightly lower satisfaction (mean 4.38) regarding incident communication suggests an opportunity to further strengthen PT. XYZ's buyer engagement during quality deviations. As indicated by Flynn et al. (2015), frequent and transparent supplier communication during disruptions significantly reduces the perceived risk and reinforces long-term buyer commitment. Therefore, formalizing proactive communication protocols—especially during shipment temperature excursions or minor quality anomalies—could further improve buyer perception.

Another noteworthy finding is the universal agreement (100%) on texture consistency, which buyers ranked as essential for product quality. This confirms that PT. XYZ has maintained process conditions that meet buyer standards across harvest batches. Previous studies Feng et al. (2019) also highlight that physical texture is one of the most sensitive indicators of cold chain performance in frozen seafood, reinforcing that consistency in this metric is a reliable proxy for operational excellence. The consistently high buyer ratings for supplier reliability and transparency (≥4.5) suggest that PT. XYZ is not only meeting quality expectations but also building long-term trust capital. As explored by Nowfal et al.(2025), such trust is essential for sustaining relationships in value-dense, export-driven agrifood chains. It also creates room for joint innovation, flexible production, and favorable contract terms.

Document Analysis

Document analysis focused on internal quality assurance records and production logs from January to March 2025. A total of 12 quality deviation reports and 6 production rework decisions were reviewed. Each document was examined for traceability linkage, timing of corrective action, and decision outcomes.

Most incidents (83.3%) were resolved within 6 hours, and all were traceable to specific production batches using the barcode-based ERP system. In cases where product integrity was compromised (e.g., odor or mislabeling), actions included rejection or immediate buyer notification.

Table 4. Summary of Quality Incident Documentation and Responses (Jan–Mar 2025)

Incident ID	Deviation Type	Time to Detect (hrs)	Action Taken	Outcome	Linked Batch Traced?
QD-01	Cold storage temp ≥ −15°C	3	Temp reset + monitoring	Within spec after 2h	Yes
QD-03	Glazing layer too thin	6	Re-glazing performed	Accepted	Yes
QD-05	Odor detected post-thaw	2	Batch rejected	Destroyed	Yes
QD-07	Foreign material in sorting line	1	Line halted, inspection	Source identified	Yes
QD-08	Broken freezer door latch	8	Repaired, staff retrained	Temp excursion mitigated	Yes
QD-10	Mislabeling of production date	24	Relabeling, report filed	Notified to buyer	Yes

The document analysis reveals that PT. XYZ has developed a functioning corrective and preventive action (CAPA) system, which ensures traceability and timely decision-making when quality deviations occur. The prompt response time (≤6 hours in most cases) reflects a mature internal governance structure, aligning with best practices in cold chain risk mitigation (Wu & Hsiao, 2021). The ability to trace all deviations to a specific batch via ERP records highlights the company's investment in digital traceability infrastructure. According to Yu et al.(2022), digital traceability systems significantly enhance the credibility of food safety responses and are increasingly demanded by buyers and regulators in high-value export markets. Furthermore, the data show that decision outcomes vary depending on the risk level of the incident. While technical deviations such as glazing inconsistencies led to rework, biological risks (e.g., off-odor post-thaw) triggered product rejection. This aligns with the risk-based quality management framework described by Lubenchenko et al. (2022), which advocates differential responses based on potential health or reputational impact.

Interestingly, one incident involving mislabeling (QD-10) required 24 hours to resolve due to administrative delays. Although ultimately communicated to the buyer, this event points to a potential gap in the label verification process that could benefit from automation or checklist reinforcement. Similar findings were reported by Rao & Shukla (2022), who emphasized the importance of real-time label validation tools in reducing compliance risk in export food systems. Overall, the findings support that PT. XYZ's documentation system is robust and operationally integrated. The traceability of incidents, alignment with CAPA protocols, and responsiveness to varying deviation types reflect a level of quality maturity consistent with GFSI-aligned certifications.

Product Quality and Buyer Perception Metrics

To better understand the relationships between product quality and buyer-related perceptions, Spearman's rank-order correlation was conducted. The following table presents the correlation coefficients and significance levels for key variables related to buyer satisfaction, trust, and product acceptance decisions.

Table 5. Correlation between Product Quality and Buyer Perception Metrics

Variable 1	Variable 2	Spearman's ρ	Sig. (2-tailed)	Interpretation
Product Quality	Buyer Satisfaction	0.672	0.001	Strong positive correlation, significant
Product Quality	Buyer Trust	0.614	0.003	Moderate to strong positive correlation, significant
Product Quality	Product Acceptance	0.719	0.000	Strong positive correlation, highly significant

The results of the Spearman's rank-order correlation analysis reveal meaningful and statistically significant associations between product quality scores and buyer perceptions. The correlation between product quality and buyer satisfaction ($\rho = 0.672$, $p = 0.001$) indicates that as product quality improves, buyer satisfaction tends to increase correspondingly. This finding aligns with previous literature emphasizing the role

of consistent product quality in ensuring customer satisfaction in seafood supply chains (Ganesan et al., 2017; Martinez & da Silva, 2020). Similarly, buyer trust showed a strong positive relationship with product quality ($\rho = 0.614$, $p = 0.003$).

This empirical relationship reinforces the Commitment-Trust Theory of relationship marketing as proposed by Morgan and Hunt (1994), which posits that trust and commitment are central to establishing and maintaining successful long-term relationships in business networks. In the context of supply chains—particularly for perishable goods such as frozen shrimp—trust functions as a mediating factor that strengthens cooperative behavior, reduces perceived risk, and enhances relationship longevity. The consistent application of cold chain protocols contributes directly to perceived reliability and integrity, thereby fostering trust among buyers. Furthermore, this trust encourages ongoing collaboration and reduces the likelihood of opportunistic behavior, in line with the core tenets of the Commitment-Trust Theory. As such, maintaining product quality through robust cold chain management is not merely a technical requirement, but a strategic imperative for relationship continuity and supplier reputation.

A very strong positive correlation was observed between product quality and product acceptance decisions ($\rho = 0.719$, $p < 0.001$), underscoring that improved cold chain control and product handling significantly enhance the likelihood of a shipment being accepted without complaint or return. This is consistent with quality assurance models in export-oriented shrimp processing industries, as discussed by Abdullah et al. (2019). These findings reinforce the notion that cold chain management directly impacts not only the technical quality of the product but also the subjective buyer experience, which in turn influences purchasing decisions and trust-based supplier relationships.

Conclusions

This study demonstrates that a consistent and well-managed cold chain significantly influences both product quality and buyer trust in frozen shrimp exports. The integration of quantitative measurements and qualitative insights reveals that non-compliance at specific critical control points—particularly in washing and processing room temperatures—poses microbiological risks that can undermine product integrity. These findings suggest an urgent need for seafood processing industries to invest in temperature stabilization technologies such as automated cooling systems, insulated processing environments, and real-time monitoring sensors. Additionally, regular training programs for cold chain personnel should be institutionalized to enhance adherence to SOPs and raise awareness of hygiene-critical practices. For government regulators, the study highlights the importance of stricter enforcement of national cold chain standards (e.g., SNI 01-4370-1996), along with the development of incentive schemes or technical assistance for small- and medium-scale enterprises to upgrade their cold chain infrastructure. By addressing these operational gaps collaboratively, both industry and government can reduce product rejection rates, improve customer satisfaction, and strengthen Indonesia's competitiveness in the global seafood market.

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