Grouper: Jurnal Ilmiah Perikanan
Vol. 17 No. 2 (2026) pp. 352 - 363
pISSN: 2086-8480 | eISSN: 2716-2702
Journal Homepage: https://grouper.unisla.ac.id/index.php/grouper

Comparative Analysis of Shrimp Freshness During Distribution from Two Suppliers to a Fish Processing Unit

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Submitted: 08 August 2026 Revised: 02 September 2026 Accepted: 15 September 2026

Keywords:
Cold-Chain Compliance; Seafood Distribution; Sensory Quality; Shrimp Freshness; TVB-N

ABSTRACT

This exploratory field study described before-and-after changes in the freshness of headless shrimp of an unrecorded taxonomic species during six deliveries from two suppliers (three per supplier) to the same fish processing unit in Banjarmasin. One pooled composite sample was obtained at loading and unloading for each delivery. Core temperature, pH, total volatile base nitrogen (TVB-N), total plate count (TPC), appearance, odor, texture, and compliance with Indonesian Good Fish Distribution Practices (Cara Distribusi Ikan yang Baik; CDIB) were described. Supplier A's mean temperature changed from 3.74 to 7.99 degrees C, whereas Supplier B's changed from 7.77 to 2.53 degrees C. Mean TVB-N changed from 19.60 to 20.97 mg N/100 g for Supplier A and from 32.54 to 34.89 mg N/100 g for Supplier B. Mean TPC values were lower after distribution (4.55 to 4.27 and 5.11 to 4.90 log CFU/g), but this pattern does not demonstrate bacterial inactivation. Mean sensory scores declined, with the largest observed decrease in Supplier B's texture score. Supplier B's aggregate CDIB score was 80.00%, compared with 74.29% for Supplier A, but the higher score was not consistently aligned with the descriptive laboratory and sensory indicators. Because n = 3 per supplier, the findings are specific to these deliveries and do not establish supplier superiority or the independent effects of icing, ice quantity, or other practices. Earlier icing, load-adjusted ice, continuous temperature recording, and control-point monitoring are operational priorities suggested by the observations rather than formally tested determinants.

INTRODUCTION

Shrimp is one of Indonesia's leading fishery commodities and requires rigorous quality assurance throughout the supply chain. In 2024, Indonesian shrimp exports were valued at USD 1.68 billion, accounting for 28.2% of the country's total fishery export value (Directorate General of Marine and Fisheries Product Competitiveness, 2025). By export value, Indonesia was the fifth-largest shrimp exporter globally, with a reported market share of approximately 6.0% (Directorate General of Marine and Fisheries Product Competitiveness, 2026). This position indicates that competitiveness depends not only on increased production but also on consistent freshness, safety, traceability, and conformity of the raw-material quality received by processors.

Shrimp is highly perishable because of its high moisture and protein contents. After death, oxygen supply ceases, initiating anaerobic glycolysis, adenosine triphosphate depletion, rigor mortis, autolysis, protein degradation, lipid oxidation, and the growth of spoilage microorganisms. The interaction of these processes produces volatile compounds, discoloration, off-odors, tissue softening, and reduced consumer acceptance (Ghaly et al., 2010; Liang et al., 2025; Lin et al., 2022). The rate of deterioration is strongly influenced by

temperature, exposure duration, initial quality, handling hygiene, and the effectiveness of cooling immediately after harvest.

Shrimp freshness should be assessed multidimensionally because no single parameter necessarily represents all mechanisms of deterioration. A core-temperature measurement describes the condition at the moment and location of measurement, not the complete thermal history. pH reflects the balance between acid formation and the later generation of basic compounds; TVB-N measures accumulated volatile bases; TPC estimates culturable aerobic bacterial load; and sensory evaluation captures observable changes in appearance, odor, and texture. Interpreting these indicators together is more informative than relying on one endpoint (Kim et al., 2020; Mohseni-Shahri & Moeinpour, 2023; Pellegrini et al., 2026; Tahuru et al., 2026).

The cold chain is intended to reduce and maintain product temperature near the melting point of ice from initial handling through storage, transportation, and receipt. Cooling suppresses enzymatic reactions and slows microbial multiplication but cannot restore quality lost before icing. Therefore, the timing of icing, contact between ice and product, cooling capacity, ice-to-load ratio, container insulation, and temperature monitoring throughout transit should be managed as an integrated control system (Azhari et al., 2023; Wang et al., 2016; Zeng et al., 2005). A low temperature at the destination does not necessarily demonstrate that the product remained cold from the beginning of distribution.

Operational context reported by the participating suppliers before sampling indicated that shrimp deliveries in South Kalimantan may require approximately 3-12 h and commonly use open-bed trucks. Products are placed in cool boxes or insulated fiberglass containers, but solar heat, melting ice, failure to adjust ice to the product load, and the absence of continuous temperature records may disrupt temperature control. These contextual statements were not standardized measurements from each of the six study deliveries and are therefore used only to frame the field setting (Arrahmi et al., 2026; Rosyidah et al., 2020).

From a regulatory perspective, Regulation of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia Number 9 of 2024 places procurement, storage, transportation, hygiene, facilities, and documentation within Indonesian Good Fish Distribution Practices (Cara Distribusi Ikan yang Baik; CDIB) (Ministry of Marine Affairs and Fisheries of the Republic of Indonesia, 2024). CDIB compliance profiles describe conformity with multiple requirements; an aggregate score does not by itself demonstrate the effectiveness of temperature control or sanitation. Two suppliers may obtain similar totals while differing at control points that are plausibly more relevant to product quality.

Indonesian studies have examined biochemical and microbiological changes in shrimp during cold chains, raw-material quality in processing facilities, and shrimp distribution systems as largely separate topics (Badrin et al., 2019; Raja et al., 2023; Rosyidah et al., 2020; Utomo et al., 2024). The exploratory contribution of the present study is the integration of paired loading-unloading observations, laboratory and sensory indicators, icing practices, and CDIB profiles for two suppliers serving the same receiving FPU. It is not designed to estimate causal effects or to rank the broader supplier population.

This exploratory study aimed to describe shrimp freshness before and after distribution from Supplier A and Supplier B to the same fish processing unit using core temperature, pH, TVB-N, TPC, appearance, odor, and texture, and to examine how the two observed cold-chain and CDIB compliance profiles aligned with those descriptive quality indicators.

METHOD

Study design, locations, and units of observation

This exploratory two-supplier case study used paired before-and-after observations at two regular shrimp suppliers in Tanah Laut Regency and Banjar Regency, South Kalimantan, and at the same receiving fish processing unit (FPU) in Banjarmasin City. Business identities were anonymized as Supplier A and Supplier B. Each supplier was observed on three separate delivery days, yielding three paired delivery-level observations per supplier and six deliveries

overall. The delivery day, represented by one composite sample at loading and one composite sample at unloading, was the observational unit. The records supplied for this manuscript did not retain the delivery dates, sampling intervals or season, route distance, departure and arrival times, journey duration, ambient temperature, per-delivery load weights, product origin, postharvest age, or standardized vehicle-condition records. These uncontrolled characteristics are confounded with supplier identity and may explain part of the observed variation.

Research materials, sampling, and distribution observations

The study material consisted of headless shrimp weighing 3-4 g per individual. The taxonomic species was not documented in the records available for this manuscript; species-specific conclusions are therefore avoided. At each of the six deliveries, a pre-distribution sample was collected during loading at the supplier premises and a post-distribution sample during unloading at the FPU. Shrimp taken from the upper, middle, and lower sections of the transport container were pooled into one composite sample of at least 1 kg for each supplier-stage-delivery combination, following the representativeness principle of SNI 2326:2010 (National Standardization Agency of Indonesia, 2010). Thus, individual shrimp, container positions, and technical laboratory replicates were subsamples rather than independent observations. Samples were aseptically packaged, coded, transported under chilled conditions targeted at 0-5 degrees C, and submitted to the designated laboratory. The exact elapsed time from collection to analysis and the time of each laboratory test were not retained; this is acknowledged as a limitation because unequal holding times may affect quality measurements.

Physical, chemical, and microbiological analyses

Core temperature was measured in the thickest portion of the tissue using a calibrated digital thermometer in accordance with SNI 01-2372.1-2006 (National Standardization Agency of Indonesia, 2006). For pH, 20 g of homogenized shrimp was mixed with 40 mL of distilled water and measured with a pH meter calibrated at pH 4 and 7. Instrument operation and calibration were adapted from SNI 06-6989.11-2004 (National Standardization Agency, 2004), a water-and-wastewater method; the matrix-specific validity of this adaptation for shrimp homogenate was not established, so pH results are treated as study-specific operational measurements. TVB-N was analyzed using the Conway microdiffusion method after extraction with 7% trichloroacetic acid and expressed as mg N/100 g, in accordance with SNI 01-4495-1998 (National Standardization Agency, 1998).

TPC was determined by serial dilution, duplicate plating on Plate Count Agar, and incubation at 35 +/- 1 degrees C for 48 h in accordance with SNI 2332.3:2015 (National Standardization Agency of Indonesia, 2015a). Duplicate plates were technical replicates and were averaged to produce one TPC value for each composite biological sample; they were not treated as independent observations. Colonies within the countable range were converted to CFU/g and log-transformed for the original exploratory analysis. pH and TVB-N were analyzed at the Fishery Product Technology Laboratory, Faculty of Fisheries and Marine Science, Lambung Mangkurat University, whereas TPC was determined at the fishery product quality control laboratory in Banjarbaru.

Sensory evaluation

Six panelists described in the source records as trained independently evaluated coded samples for appearance, odor, and texture. Evaluation followed SNI 2346:2015 and interpretation followed SNI 2728:2018 (National Standardization Agency of Indonesia, 2015b, 2018). The ordinal scale used the available category scores of 9 (very fresh), 7 (fresh/acceptability limit), and 5 (initial deterioration). Panelist scores were averaged for each attribute and delivery day. The records did not specify the duration or content of panelist training, calibration performance, serving order, blinding beyond sample coding, randomization, room conditions for each session, or inter-rater reliability. Individual panelist scores were also unavailable. Accordingly, sensory results are reported as descriptive aggregate scores and no claim is made that reliability was formally established.

Assessment of Good Fish Distribution Practices

CDIB compliance was assessed once for each supplier during the study period by direct observation using 35 binary checklist items derived from Ministerial Regulation Number 9 of 2024 (Ministry of Marine Affairs and Fisheries of the Republic of Indonesia, 2024). The items covered hygiene standards (10), handling techniques (12), and infrastructure, equipment, and facilities (13). The score equaled the number of compliant items divided by 35 and multiplied by 100%. The available records did not identify the assessor's qualifications, repeat-assessment frequency, supporting document numbers, photographs, or independent verification of each item. All items were equally weighted, although their consequences for product quality may differ. The score is therefore a descriptive compliance profile, not a validated causal measure of cold-chain effectiveness.

Data analysis

The delivery day was the biological unit of analysis (n = 3 paired deliveries per supplier). Given this very small case series, the revised analysis is descriptive. Results are reported as stage-specific means +/- standard deviations, observed delivery-level values where retained, and absolute after-minus-before changes in the original measurement units. Percentage changes in Celsius temperature are not calculated because the Celsius scale has an arbitrary zero. Normality testing and paired or between-supplier hypothesis tests were removed: with only three deliveries per supplier, such tests have very low diagnostic and inferential value, and the complete raw paired dataset, test statistics, degrees of freedom, exact p-values, effect estimates, confidence intervals, and software records were unavailable for independent verification. No missing values were imputed. The findings do not establish equivalence, supplier superiority, or causal effects.

RESULT AND DISCUSSION

Operational characteristics of the cold chain

Supplier A and Supplier B showed different observed chilling profiles (Table 1). Supplier A applied pre-chilling several hours before departure, whereas Supplier B added ice shortly before departure. The source records expressed the product-to-ice ratio as 1:x, where 1 represents shrimp mass and x represents ice mass; thus, 1:0.45 means 1 kg shrimp to 0.45 kg ice. Supplier A's recorded product-to-ice ratio varied more across deliveries, while Supplier B's was more stable. These observations do not isolate the independent effect of icing time or ice quantity. Loading and unloading temperatures are endpoints and do not represent the complete thermal history.

Table 1. Comparison of operational cold-chain practices between the two suppliers.

Component	Supplier A	Supplier B	Quality implication
Timing of icing	Pre-chilled several hours before departure	Ice added shortly before departure	Earlier versus later icing was observed; its independent effect was not tested
Product-to-ice ratio (kg shrimp:kg ice)	1:0.45, 1:0.42, and 1:0.26	Approximately 1:0.39-1:0.45	The first value is shrimp mass and the second is ice mass; associations were not tested causally
Initial–final temperature	3.74 to 7.99 °C	7.77 to 2.53 °C	Endpoint temperatures differed; complete thermal histories were unavailable

Component	Supplier A	Supplier B	Quality implication
Main risk	Ice quantity not adjusted to increased load	Delayed icing and no continuous temperature records	Potential priorities identified from observations, not tested determinants

Changes in core temperature

Supplier A's mean temperature increased by 4.25 degrees C, from 3.74 +/- 1.67 to 7.99 +/- 5.33 degrees C (Table 2). The three retained post-distribution temperatures were 5.23, 4.60, and 14.13 degrees C. The value of 14.13 degrees C on the third delivery contributed to the large dispersion and represents an operationally relevant observation. Supplier A's loading mean was below 5 degrees C, whereas its unloading mean and two of the three unloading measurements were above 5 degrees C. These descriptive endpoints should not be interpreted as evidence that a specific practice caused the change.

The third Supplier A delivery combined the highest retained unloading temperature with the lowest recorded ice quantity relative to shrimp (product-to-ice ratio 1:0.26). This co-occurrence is operationally relevant but does not establish causation because load weight, ambient temperature, journey duration, insulation performance, and other delivery characteristics were not controlled. Ice requirements should be specified prospectively according to product mass and measured transport conditions (Azhari et al., 2023; Wang et al., 2016; Zeng et al., 2005).

Supplier B's mean temperature was 5.24 degrees C lower at unloading than at loading (7.77 +/- 2.65 to 2.53 +/- 0.52 degrees C). Ice was recorded as having been added shortly before departure, and the unloading mean was within the chilled range. Because only endpoint temperatures were available, the timing and trajectory of cooling are unknown. The lower unloading temperature is an association in these deliveries and should not be interpreted as proof that icing restored freshness or caused a quality improvement.

Table 2. Physical, chemical, and microbiological quality of shrimp before and after distribution.

Parameter	A before	A after	Mean change in A	B before	B after	Mean change in B
Temperature (°C)	3.74 ± 1.67	7.99 ± 5.33	+4.25 degrees C	7.77 ± 2.65	2.53 ± 0.52	-5.24 degrees C
pH	8.03 ± 0.06	8.03 ± 0.06	0.00	7.95 ± 0.00	7.93 ± 0.06	−0.02 (0.25%)
TVB-N (mg N/100 g)	19.60 ± 4.33	20.97 ± 2.65	+1.37 (7.0%)	32.54 ± 10.52	34.89 ± 11.13	+2.35 (7.2%)
TPC (log CFU/g)	4.55 ± 0.44	4.27 ± 0.35	−0.28 log	5.11 ± 0.55	4.90 ± 0.78	−0.21 log

Note: Values are means +/- standard deviations from three delivery days; change values are absolute after-minus-before differences in the original measurement units. Percentage change is not reported for Celsius temperature. Stage-specific standard deviations describe dispersion and are not uncertainty estimates for paired effects. Complete raw paired observations were unavailable and were not reconstructed. TVB-N = total volatile base nitrogen; TPC = total plate count.

pH values and biochemical interpretation

The pH of shrimp from Supplier A remained unchanged at 8.03 ± 0.06 before and after distribution. For Supplier B, the pH decreased only slightly, from 7.95 ± 0.00 to 7.93 ± 0.06. The overall range of 7.93–8.03 indicates that pH was relatively unresponsive during the short distribution period. After death, pH may initially decrease because of lactic acid accumulation and subsequently increase as autolysis and microbial activity generate ammonia and volatile

amines (Ghaly et al., 2010; Kim et al., 2020; Mohseni-Shahri & Moeinpour, 2023; Pellegrini et al., 2026). When these two processes occur in close succession, the net change may be small.

A stable pH does not indicate an absence of deterioration. Values close to or slightly above 8.0 should be interpreted together with TVB-N and sensory data because the samples had already undergone handling, sorting, and preparation before collection. Tahuru et al. (2026) reported that changes in shrimp pH are influenced by initial conditions and cooling effectiveness, whereas Nurhayati et al. (2018) described the dynamics of rigor and autolysis in whiteleg shrimp. In the present study, TVB-N and texture discriminated quality more clearly than pH.

Changes in TVB-N as an indicator of spoilage accumulation

TVB-N in shrimp from Supplier A increased from 19.60 ± 4.33 to 20.97 ± 2.65 mg N/100 g, whereas that in shrimp from Supplier B increased from 32.54 ± 10.52 to 34.89 ± 11.13 mg N/100 g. The relative increases were similar at approximately 7%, but the initial values differed markedly. According to the classification of Rahmat et al. (2019), values of 20–30 mg N/100 g represent the acceptable freshness limit, whereas values >30 mg N/100 g indicate a non-fresh condition. Thus, Supplier A's shrimp shifted toward the acceptability threshold, whereas Supplier B's shrimp had already exceeded this threshold before departure.

Supplier B's stage-specific TVB-N standard deviations exceeded 10 mg N/100 g. The retained loading values for its three deliveries were 23.52, 44.10, and 29.99 mg N/100 g, indicating substantial delivery-to-delivery variation. Mean differences between the two supplier cases were 12.94 mg N/100 g at loading and 13.92 mg N/100 g at unloading, but these descriptive contrasts are confounded by initial raw-material quality, product origin, postharvest age, route, journey duration, icing, and other uncontrolled factors. They do not support a general supplier ranking.

TVB-N is formed through amino acid deamination, trimethylamine oxide reduction, and degradation of nitrogenous compounds by endogenous enzymes and microorganisms (Hastarini et al., 2014; Kim et al., 2020; Mohseni-Shahri & Moeinpour, 2023; Pellegrini et al., 2026). Supplier B's lower unloading temperature could have slowed subsequent formation, but the present design did not test the relative contributions of initial quality, icing time, transit conditions, or other factors. The results therefore support a descriptive observation of different initial and final profiles, not a causal ranking of determinants.

Total plate count and microbiological quality

Mean TPC was lower after distribution for Supplier A (4.55 +/- 0.44 to 4.27 +/- 0.35 log CFU/g) and Supplier B (5.11 +/- 0.55 to 4.90 +/- 0.78 log CFU/g). The final means for both suppliers were below the 5 log CFU/g limit specified in SNI 2728:2018 (National Standardization Agency of Indonesia, 2018), although Supplier B's loading mean slightly exceeded this value. These mean patterns indicate that microbiological quality should be evaluated from loading onward, but they do not demonstrate bacterial inactivation during transit.

Low temperature is primarily bacteriostatic: it slows cellular metabolism and division but does not immediately kill bacteria (Herawati et al., 2020; Liang et al., 2025; Lin et al., 2022; Zeng et al., 2005). Each supplier-stage-delivery value represented one pooled composite biological sample; duplicate plates were technical replicates. With only three biological observations per stage, differences of 0.21-0.28 log may reflect product heterogeneity, sampling, dilution, and colony enumeration. The cautious interpretation is that no increase in mean TPC was observed, not that transportation reduced the bacterial population.

The pattern of decreasing TPC alongside increasing TVB-N demonstrates that these indicators represent different dimensions or stages of deterioration. TPC represents aerobic microorganisms that can grow under the test conditions (National Standardization Agency of Indonesia, 2015a), whereas TVB-N reflects the accumulation of degradation products that do not disappear when the temperature decreases. Endogenous enzymatic activity may also

continue at low temperatures. Raw-material acceptance should therefore not rely solely on TPC but should combine TPC with TVB-N, temperature, and sensory evaluation.

Changes in sensory quality

Mean sensory scores were lower after distribution (Table 3). Absolute mean changes for Supplier A were -0.11 points for appearance, odor, and texture. For Supplier B, the respective changes were -0.34, -0.45, and -0.67 points. SNI 2728:2018 specifies a minimum sensory score of 7 for fresh shrimp (National Standardization Agency of Indonesia, 2018). Delivery-level averages below 7 do not reveal how many individual ratings failed the criterion, and averaging ordinal ratings can conceal unacceptable observations. These patterns are therefore descriptive rather than statistically supported differences.

Table 3. Sensory scores of shrimp before and after distribution.

Attribute	A before	A after	Change in A	B before	B after	Change in B
Appearance	7.00 ± 0.00	6.89 ± 0.19	-0.11	6.78 ± 0.39	6.44 ± 0.51	-0.34
Odor	6.89 ± 0.19	6.78 ± 0.39	-0.11	6.89 ± 0.19	6.44 ± 0.51	-0.45
Texture	7.00 ± 0.00	6.89 ± 0.19	-0.11	6.89 ± 0.19	6.22 ± 0.19	-0.67

Note: Values are delivery-level means +/- standard deviations for three delivery days, based on six trained panelists using ordinal scores of 5, 7, and 9. Individual panelist ratings and counts below the acceptability threshold were unavailable in the supplied records.

The decline in appearance was characterized by reduced brightness, weaker intersegmental connections, and the possible development of dark spots. Polyphenol oxidase oxidizes phenolic compounds into melanin pigments, causing the shrimp surface to lose its natural gloss (Montero et al., 2004; Sipahutar et al., 2020). Although melanosis does not necessarily indicate a microbiological hazard, it reduces visual acceptance and is an important sign of quality deterioration for processors and consumers.

Odor scores decreased as TVB-N increased. Ammonia, trimethylamine, dimethylamine, and volatile sulfur compounds formed during autolysis and bacterial activity shift the characteristic fresh odor toward a neutral odor, a strong fishy odor, and eventually a putrid odor (Kim et al., 2020; Mohseni-Shahri & Moeinpour, 2023; Pellegrini et al., 2026). Standardized sensory evaluation enables these changes to be assessed consistently, but it should be combined with chemical and microbiological data to reduce reliance on a single type of indicator (National Standardization Agency of Indonesia, 2015b; Sholehah & Hafiludin, 2022).

Texture showed the largest observed mean decrease among the three sensory attributes, especially for Supplier B; sensitivity was not formally compared or validated. Softening can occur when endogenous proteases degrade myofibrillar proteins and connective tissue, reducing elasticity, firmness, and water-holding capacity. Zhan et al. (2023) demonstrated the role of trypsin-like protease in shrimp muscle-protein degradation during chilled storage. In this dataset, Supplier B also had higher mean TVB-N and TPC at loading, so the larger texture change cannot be attributed to distribution practices alone.

Descriptive comparison between supplier cases

Across the six observed deliveries, Supplier A had lower stage-specific mean TVB-N and TPC values and smaller absolute sensory-score changes, whereas Supplier B had a lower unloading temperature. These contrasts cannot be separated from differences in initial raw-material quality, product origin, postharvest age, route, journey duration, icing practices, and other uncontrolled operational characteristics. No hypothesis test or effect estimate is presented because the complete delivery-level dataset was unavailable and n = 3 per supplier is inadequate for stable supplier-level inference.

Indonesian Good Fish Distribution Practices compliance and alignment with quality indicators

Supplier A complied with 26 of 35 CDIB items (74.29%), whereas Supplier B complied with 28 items (80.00%) (Table 4). Both exceeded the 61% administrative threshold. Because the checklist was assessed once per supplier, assessor qualifications and item-level evidence were not retained, and all 35 items were equally weighted, the totals should be treated as descriptive profiles. Supplier B's higher aggregate score was not consistently aligned with the stage-specific laboratory and sensory means, but this observation does not establish the effectiveness or causal importance of any checklist item.

Table 4. Indonesian Good Fish Distribution Practices (CDIB) assessment results for the two suppliers.

Assessment aspect	Number of items	A compliant	A (%)	B compliant	B (%)
Hygiene standards	10	8	80.00	9	90.00
Handling techniques	12	10	83.33	10	83.33
Infrastructure, equipment, and facilities	13	8	61.54	9	69.23
Total	35	26	74.29	28	80.00

Note: Total percentages were calculated against the 35 assessment items. The minimum compliance threshold for a certificate application is 61% (Ministry of Marine Affairs and Fisheries of the Republic of Indonesia, 2024).

Supplier A's recorded nonconformities concerned building conditions and supporting facilities, including proximity to a market, wooden flooring, and absence of equipment labels, written procedures, hygiene records, and employee lockers. Its lower loading temperature co-occurred with recorded pre-chilling, but pre-chilling cannot be identified as the cause. The third delivery's high unloading temperature (14.13 degrees C) co-occurred with the lowest recorded ice quantity relative to shrimp; this observation identifies a monitoring priority rather than a tested causal mechanism.

Supplier B's recorded nonconformities included absence of a hygiene standard operating procedure, temperature-monitoring reports, equipment-sanitation records, and periodic cleaning records. Ice was added shortly before departure, and a high loading temperature was observed; however, the present case study cannot attribute that temperature to icing time alone. The higher total CDIB score did not eliminate gaps at potentially important control points. Follow-up should prioritize rapid chilling, adequate ice, sanitation, continuous temperature monitoring, traceability, and documented corrective action.

Synthesis of findings, implications, and limitations

The comparison should not be interpreted as evidence that one supplier was generally superior. Supplier A had lower mean TVB-N and TPC at loading and smaller mean sensory changes, but its unloading temperature was variable. Supplier B reached a lower mean unloading temperature, but its loading TVB-N and TPC means were higher. The higher aggregate CDIB score for Supplier B was therefore not consistently aligned with the descriptive laboratory and sensory indicators in these six deliveries. The observations suggest different improvement priorities - load-adjusted ice for Supplier A and earlier icing plus documented hygiene and temperature control for Supplier B - but the independent effects of these actions were not tested.

For the FPU, incoming inspection should combine temperature measurement, rapid sensory assessment, and review of temperature-history records; TVB-N and TPC analyses should be conducted periodically to verify supplier performance. Data loggers positioned at the upper, middle, and lower sections of containers could detect fluctuations missed by endpoint

measurements. Suppliers should also establish critical temperature limits, ice-addition rules, the maximum allowable time before icing, sanitation frequencies, and corrective actions when products deviate from specified limits. This approach is consistent with distribution quality-assurance objectives and would improve the consistency of raw materials supplied for processing (Arrahmi et al., 2026; Azhari et al., 2023; Badrin et al., 2019; Ministry of Marine Affairs and Fisheries of the Republic of Indonesia, 2024; Raja et al., 2023; Rosyidah et al., 2020; Utomo et al., 2024; Wang et al., 2016).

This exploratory two-supplier case study was limited to three delivery days per supplier. Species identity, continuous temperature data, delivery dates, season, journey duration, route distance, departure and arrival times, ambient temperature, load weight, vehicle condition, product origin, postharvest age, exact ice mass, and collection-to-analysis time were not retained for every delivery. Supplier identity was therefore confounded with initial quality and multiple uncontrolled operational characteristics. Composite samples obscured within-container variation, while sensory training details, individual ratings, randomization records, and reliability estimates were unavailable. CDIB was assessed once per supplier using equally weighted items without retained assessor qualifications or complete supporting evidence. The complete paired raw dataset and statistical records were also unavailable; therefore, inferential analyses were removed rather than reconstructed. Findings are descriptive, associative, and specific to these six deliveries.

CONCLUSION

In this exploratory two-supplier, six-delivery case study, stage-specific mean temperatures, TVB-N, TPC, and sensory scores differed between loading and unloading, but the design supports description rather than causal attribution or general supplier ranking. Supplier A's mean temperature changed from 3.74 to 7.99 degrees C and was highly variable at unloading. Supplier B's mean temperature changed from 7.77 to 2.53 degrees C, while its mean TVB-N was already higher at loading and remained higher at unloading (32.54 and 34.89 mg N/100 g). Supplier B's higher aggregate CDIB score (80.00% versus 74.29%) was not consistently aligned with the descriptive quality indicators. Earlier icing, shrimp-mass-based ice rules, continuous temperature records, sanitation, and documented corrective actions are reasonable management priorities, but their effects require evaluation with identified species, complete raw data, more deliveries, and measured transport covariates.

AKNOWLEDGMENTS

The authors thank both suppliers and the fish processing unit for facilitating sample collection, the Fishery Product Technology Laboratory at Lambung Mangkurat University, and the fishery product quality control laboratory in Banjarbaru for their support during laboratory analyses.

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