Supply chain integration and economic sustainability of traditional salted fish processing: evidence from *Scomberoides tol* (Cuvier, 1832) in Sibolga City, Indonesia

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Abstract. This study examines the influence of supply chain integration on the economic sustainability of traditional salted needlescale queenfish, *Scomberoides tol* (Cuvier, 1832) processing in Sibolga City, North Sumatra. The research aims to identify alternative supply chain structures, evaluate their financial performance and business feasibility, and assess the implications of integration for sustaining production and livelihoods under seasonal variability. A mixed-methods approach was applied, combining descriptive analysis with financial indicators, including the revenue-cost ratio (R/C), the benefit-cost ratio (BCR), the payback period (PP), the return on investment (ROI), and the break-even point (BEP). In 2024, total production reached 13,641 kg with a total value of USD 8,830, underscoring the economic relevance of traditional salted fish processing. Two dominant supply chain models were identified. The more integrated and shorter supply chain exhibited superior financial performance, with an average annual profit of USD 1,200, a BCR of 2.88, an ROI of 47.55%, and a PP of 2.25 years. In contrast, the less integrated supply chain showed lower profitability and efficiency, reflected by a BCR of 1.27, an ROI of 29.87%, and a PP of 3.75 years. These findings indicate that stronger coordination among supply chain actors enhances economic viability, production efficiency, and resilience to seasonal fluctuations, supporting sustainable economic outcomes and responsible production in small-scale coastal fish processing systems.
Key Words: coastal livelihoods, economic sustainability, responsible production, small-scale fisheries, supply chain integration.

Introduction. Small-scale fisheries play an essential role in supporting coastal economies in maritime countries, particularly through employment generation and food provision. In Indonesia, capture fisheries contribute significantly to household livelihoods and regional economies; however, the economic benefits derived from these activities are strongly influenced by post-harvest processing and market organization rather than by resource availability alone (Bassett et al 2022; Phelan et al 2023). Inefficient post-harvest handling and weak coordination among supply chain actors often limit value addition and constrain income generation at the small-scale level, thereby undermining the long-term viability of fisheries-based livelihoods.

Traditional salted fish processing represents one of the most widespread post-harvest activities in Indonesian coastal communities. This sector is characterized by labor-intensive production, simple technology, and a strong dependence on seasonal raw material supply. Despite relatively low capital requirements, traditional salted fish processing contributes substantially to household income and regional fish trade, particularly in areas where access to cold storage and modern processing facilities remains limited. Consequently, economic outcomes in this sector depend not only on production

volume but also on the effectiveness of processing practices, market access, and the degree of integration within downstream supply chains.

Sibolga City, located on the western coast of North Sumatra, provides a relevant context for examining these dynamics. As an important fishing port, Sibolga supplies a wide range of processed fish products to both local and interregional markets, including Medan, Pekanbaru, and Jakarta (Siregar & Ritonga 2023; Sibolga 2024). Among these products, salted needlescale queenfish, *Scomberoides tol* (Cuvier, 1832), occupies a prominent position due to its relatively high market value, firm flesh texture, and suitability for salting and drying processes that enhance product durability and consumer acceptance.

Product quality and market value in traditional salted fish processing are closely linked to raw material freshness and processing practices. Previous studies on high-value salted fish products in Indonesia, such as jambal roti, have demonstrated that careful handling of raw materials and controlled processing stages contribute significantly to product differentiation and price premiums (Sumarno et al 2020; Wibawa et al 2025). Similar principles apply to salted *S. tol*, where the ability to maintain quality throughout processing and distribution directly influences economic returns at the processor level.

However, economic performance in traditional salted fish processing systems remains strongly affected by seasonal variability and supply chain organization. Fluctuations in fish landings lead to unstable production volumes, while reliance on sun-drying methods exposes processors to weather-related risks and inconsistent output quality. Limited access to capital and processing technology further constrains efficiency. More critically, weak coordination and limited vertical integration among fishers, processors, and traders often increase transaction costs, reduce bargaining power, and result in uneven value distribution along the supply chain (Leiwakabessy et al 2021; Rahmat & Neilson 2023).

From a sustainability perspective, short-term economic performance does not necessarily translate into long-term economic sustainability. Economic sustainability in small-scale fisheries refers to the capacity of enterprises and livelihoods to maintain viable income levels, recover investments, and withstand seasonal and market-related uncertainties over time (FAO 2015; FAO 2018a). In developing-country contexts, sustainability is shaped by economic, institutional, and organizational conditions that enable actors to adapt to variability and sustain livelihoods beyond short-term profitability (Kosamu 2015). Within this framework, supply chain integration plays a critical role by improving coordination, stabilizing input supply, enhancing price transmission, and reducing exposure to production and market risks. Financial indicators such as profitability, break-even points (BEP), payback periods (PP), and returns on investment are therefore interpreted not merely as measures of economic performance, but as proxies for economic sustainability when assessed in relation to risk exposure, capital recovery, and resilience to seasonal variability.

While numerous studies have examined supply chain structures and economic performance in small-scale fisheries, most focus on short-term profitability indicators and pay limited attention to long-term economic sustainability amid seasonal variability. Empirical evidence linking differing levels of supply chain integration with income stability, risk exposure, and business continuity in traditional salted fish processing systems remains limited, particularly in developing coastal regions. In response, this study analyzes how differing levels of supply chain integration influence the economic sustainability of traditional *S. tol* processing in Sibolga City, North Sumatra, by comparing alternative supply chain structures, evaluating their financial performance and risk profiles, and examining their capacity to enhance resilience to seasonal fluctuations. By explicitly linking financial indicators, supply chain organization, and seasonal dynamics, this study contributes empirical evidence on how varying levels of supply chain integration shape economic sustainability rather than merely economic performance in small-scale, traditional fish processing systems.

Material and method. This study employed a mixed-methods research design to analyze the relationship between supply chain integration and economic sustainability in traditional salted fish processing. Quantitative and qualitative data were collected simultaneously and integrated during the analysis stage to provide a comprehensive assessment of both financial performance and supply chain structure.

The study population consisted of the main actors involved in the *S. tol* supply chain in Sibolga City. These actors included fishers who harvest needlescale queenfish as raw material, small-scale processors engaged in traditional salted fish production, and fish traders operating as collectors and retailers responsible for product distribution and marketing. In addition, institutional stakeholders from relevant government agencies were included to capture policy and regulatory perspectives related to fisheries management and small-scale processing development. These institutions comprised the Sibolga City Fisheries Office, the Regional Development Planning Agency (Bappeda), and the Sibolga Ocean Fishing Port Authority (Sibolga 2024).

By incorporating multiple actor groups across different stages of the supply chain, this study was able to capture variations in supply chain integration, coordination mechanisms, and economic outcomes. This approach provided a holistic understanding of how interactions among fishers, processors, traders, and institutions influence the economic sustainability of traditional *S. tol* processing.

Study area and research period. The study was conducted in Sibolga City, North Sumatra Province, Indonesia, a coastal city located on the western shoreline of Sumatra Island that functions as an important center for capture fisheries and traditional salted fish processing. Sibolga was selected due to its long-established salted fish industry and its role as a regional distribution hub supplying processed fish products to both local and interregional markets. The geographical location of the study area is presented in Figure 1.

Field activities focused on coastal zones where fishing and processing activities are concentrated, as well as the Pasar Belakang area, which serves as a traditional market and primary collection point for salted fish distribution and trade. Data collection was conducted over three months from July to September 2025, coinciding with active processing and trading activities.

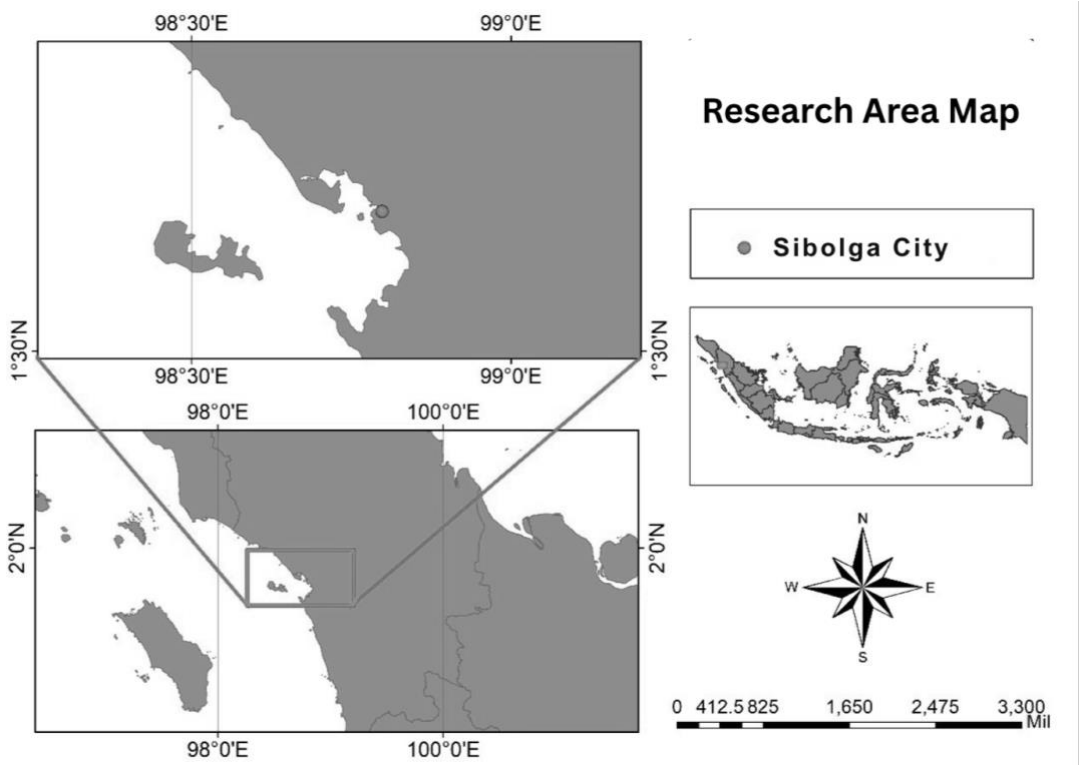

Figure 1. Research location at Sibolga City, North Sumatra, Indonesia

Sampling and respondents. Respondents were selected using purposive and quota sampling techniques to ensure adequate representation of actors directly involved in the traditional salted fish supply chain and possessing sufficient operational experience. Inclusion criteria comprised active engagement in fishing, processing, or trading activities, continuity of operation during the study period, and regular involvement in salted fish production or distribution. This approach was adopted to capture economically relevant practices rather than to generate statistically representative population estimates.

The quantitative survey included a total of 50 respondents (n = 50), consisting of 20 fishers, 10 salted fish processors, and 20 traders (collectors and retailers). This sample size was considered appropriate because the analysis focuses on an in-depth economic assessment of a relatively homogeneous small-scale processing system. In addition, the selected respondents represent a substantial proportion of active supply chain actors in the study area, enabling meaningful comparison between different supply chain structures and levels of integration.

Based on dominant marketing roles and transaction pathways, respondents were classified into two empirically observed supply chain models. Supply Chain I comprised 30 respondents, primarily salted fish processors who also functioned as retailers by selling products directly to final consumers through local markets or direct sales channels. In contrast, Supply Chain II involved 20 respondents, consisting mainly of retailers and traders who purchased salted fish products from processors and distributed them to consumers through intermediary market channels.

Several actors, particularly processors, were found to participate in both supply chain arrangements by combining direct sales to consumers with sales through retailers. To avoid double-counting and ensure analytical clarity, respondents were assigned to a supply chain model based on their dominant operational role, defined as the marketing channel contributing the largest share of their annual sales volume during the study period.

In addition to the quantitative survey, in-depth interviews were conducted with 3-6 key institutional informants representing government agencies and related organizations. These informants were not included in the financial analysis but provided complementary contextual insights into fisheries policies, infrastructure support, regulatory frameworks, and institutional factors influencing the development and economic sustainability of traditional salted fish processing in Sibolga City.

Data collection methods. Seasonal production data were obtained from official fisheries statistics provided by the Nusantara Fishing Port of Sibolga City. These secondary data consist of monthly production records for a single year (2014) and were used to describe general seasonal patterns in raw material availability and production dynamics throughout the year. This dataset was employed to capture representative seasonality trends rather than short-term or year-specific fluctuations.

Primary data were collected through fieldwork conducted between August and September 2025 using three complementary techniques: structured interviews, semi-structured interviews, and direct field observations. Structured interviews were conducted using questionnaires designed to obtain quantitative information on respondents' socio-economic characteristics, production and marketing practices, cost and revenue components, and participation in different supply chain arrangements. These data formed the basis for the financial feasibility and performance analysis.

Semi-structured interviews with key informants were used to explore qualitative aspects of supply chain integration, including coordination mechanisms among actors, market access, institutional support, and perceived challenges affecting economic sustainability. This approach facilitated a deeper understanding of relational dynamics and governance structures within the salted fish value chain.

Direct field observations were undertaken to document traditional *S. tol* processing activities, including raw material handling, gutting, washing, wet salting (approximately one-day soaking), seasoning, and sun drying. Observations also covered supporting infrastructure, hygiene practices, product packaging, and marketing activities in local markets, thereby providing contextual insights into operational constraints, quality control practices, and post-harvest management conditions.

Supply chain structure and actor classification. Supply chain integration in this study was defined based on observable structural and functional characteristics rather than analytical assumptions. A supply chain was classified as integrated when processors were directly involved in downstream marketing activities, including direct sales to final consumers, resulting in shorter marketing channels and reduced reliance on intermediaries. Additional integration criteria included the number of intermediary actors involved, the degree of coordination between processors and market actors, and the extent of price-setting control at the processor level. Based on these criteria, two empirical supply chain models were identified and analyzed.

Data analysis. Quantitative data were analyzed descriptively to characterize business operations, cost structures, and revenue patterns across different supply chain models. Family labor was not monetized and was treated as an in-kind contribution, while depreciation was excluded due to limited records of equipment age and purchase value. Therefore, profitability indicators may be slightly overestimated, although comparisons between supply chain models remain valid because the same accounting approach was applied across groups.

Financial performance and business feasibility were evaluated using standard economic indicators, including the revenue-cost ratio (R/C), benefit-cost ratio (BCR), return on investment (ROI), PP, and BEP. These indicators were used to compare economic outcomes between supply chains with different levels of integration. All financial indicators were calculated on an annual basis using average annual cost and revenue data, including BEP values, which represent the minimum annual output/price required to cover total costs (Kadariah et al 1999; Nurmalina et al 2018)

Revenue-cost ratio (R/C): measures the relationship between total revenue and total production cost to assess business feasibility. An R/C value greater than 1 indicates that the business is economically feasible.

$$\mathrm{R/C} = \frac{\mathrm{TR}}{\mathrm{TC}}$$

Where:
R = Revenue
C = Cost
TR = Total revenue
TC = Total cost

Benefit-cost ratio (BCR): A BCR value greater than 1 indicates that benefits exceed costs and the enterprise is financially viable.

$$\mathrm{BCR} = \frac{\mathrm{TR}}{\mathrm{TC}}$$

Where:
BCR = Benefit-Cost Ratio
TR = Total revenue
TC = Total cost

Return on investment (ROI): measures the ability of the enterprise to generate profit relative to the invested capital. Higher ROI values indicate more efficient capital utilization.

$$\mathrm{ROI} = \frac{\text{Net Profit}}{\text{Total Investmen}} \mathrm{x}100\%$$

Where:
ROI = Return on investment
Net Profit (NP) = net earnings (total revenue - total cost)
Total Investment (TI) = total capital invested (e.g., initial capital/expenditures used)
100% = multiplier to express the ratio as a percentage

The payback period (PP): A shorter PP indicates faster capital recovery and lower investment risk.

$$\mathrm{PP} = \frac{\text{Amount of annual investmen}}{\text{Annual profit}}$$

Where:
PP = Payback period
Amount of annual investment (AI) = total investment/capital outlay allocated for the project/business (per year, if specified)
Annual profit (AP) = net profit earned per year

Break-Event Points (BEP): determines the minimum production level required to cover total costs. Lower BEP values indicate lower operational risk and a wider safety margin.

$$\mathrm{BEPvolume} = \frac{\mathrm{FC}}{\mathrm{P} - \mathrm{VC}}$$

Where:
BEP_{volume} = Break-even point in volume (units of product)
FC = Fixed cost (USD)
P = Selling price per unit (USD kg^{-1})
VC = Variable cost per unit (USD kg^{-1})

Qualitative data obtained from interviews and observations were analyzed thematically to identify recurring patterns related to supply chain structure, coordination mechanisms, constraints, and strategies influencing economic sustainability. Finally, triangulation was applied to integrate quantitative and qualitative findings, allowing for a comprehensive interpretation of how supply chain integration affects financial performance, efficiency, and long-term economic sustainability of traditional *S. tol* processing in Sibolga City.

Results and Discussion

Supply chain structure and actor integration. The *S. tol* supply chain in Sibolga City operates within a small-scale fisheries system involving three main actor groups: fishers, processors, and traders. These actors are connected through two dominant supply chain models that differ in their degree of vertical integration and market access. Supply Chain I represents a short and integrated structure, in which processors directly procure raw fish from fishers and sell processed products directly to final consumers. In contrast, Supply Chain II involves additional intermediary actors, resulting in a longer distribution channel and lower coordination among supply chain participants.

The socioeconomic characteristics of supply chain actors are summarized in Table 1. Fishers are predominantly male and concentrated within the productive age group of 30-50 years, reflecting the physically demanding nature of capture fisheries. In contrast, processors and traders exhibit greater gender diversity, with women playing a prominent role in post-harvest processing and marketing activities. This gendered division of labor is widely observed in small-scale fisheries and underscores the central role of women in value-adding activities rather than in harvesting operations.

Differences in education levels among actor groups indicate varying capacities for coordination and market engagement. Fishers generally exhibit lower levels of formal education, while processors and traders show higher proportions of senior high school and tertiary education. These disparities influence decision-making capacity, access to market information, and the ability to participate in more integrated supply chain arrangements. Processors, who occupy a strategic position between production and marketing stages, record the highest average monthly income, highlighting their role as key value creators within the supply chain.

Table 1
Socioeconomic characteristics of actors involved in the *Scomberoides tol* supply chain in Sibolga City

Characteristic	*Fishers*	*Processors*	*Traders*
	Gender		
Male	20 (100%)	6 (60%)	12 (60%)
Female	0	4 (40%)	8 (40%)
	Age (years)		
30-40	11 (55%)	2 (20%)	9 (45%)
41-50	6 (30%)	4 (40%)	7 (35%)
51-60	3 (15%)	2 (20%)	2 (10%)
> 60	0	2 (20%)	2 (10%)
	Education level		
Elementary School	12 (60%)	2 (20%)	6 (30%)
Junior High School	4 (20%)	3 (30%)	6 (30%)
Senior High School	4 (20%)	5 (50%	5 (25%)
Bachelor's Degree (S1)		0	3 (15%)
Average Monthly Income (USD)	167	278	173

Variations in actor roles and levels of integration significantly affect value distribution along the chain. Previous studies have shown that mapping traditional fish processing activities into more structured business models can clarify actor relationships, strengthen coordination, and improve strategic decision-making in small-scale processing systems (Yolandika et al 2023). Marketing practices further illustrate the degree of integration among actors. Most traders apply mixed sales strategies that combine direct transactions in traditional markets with limited use of online platforms, reflecting early forms of market integration and adaptation to changing consumer behavior.

Processors operating within Supply Chain I benefit from direct access to end consumers, enabling greater price control and reduced dependence on intermediaries. Consequently, more integrated actors are better positioned to capture value added and manage transaction costs more effectively. Overall, the interaction between actor characteristics and supply chain structure shapes the degree of integration and operational efficiency within the *S. tol* supply chain. These findings are consistent with broader evidence from small-scale fisheries, where improved coordination and reduced intermediary layers contribute to enhanced value capture and lower economic vulnerability (Gereffi et al 2005; Arvitrida et al 2019; Bassett et al 2022).

Production dynamics, seasonality, and economic implications. Production of needlescale queenfish in Sibolga City during 2024 exhibited pronounced monthly variability, reflecting strong seasonality in both production volume and economic value (Figure 2). Peak production occurred in March and May, when favorable fishing conditions and higher availability of raw materials enabled processors to operate at higher capacity. In contrast, the lowest production levels were recorded in October, indicating a period of limited raw material supply and reduced processing activity. Overall, total annual production reached 13,641 kg, generating a total production value of USD 8,830.

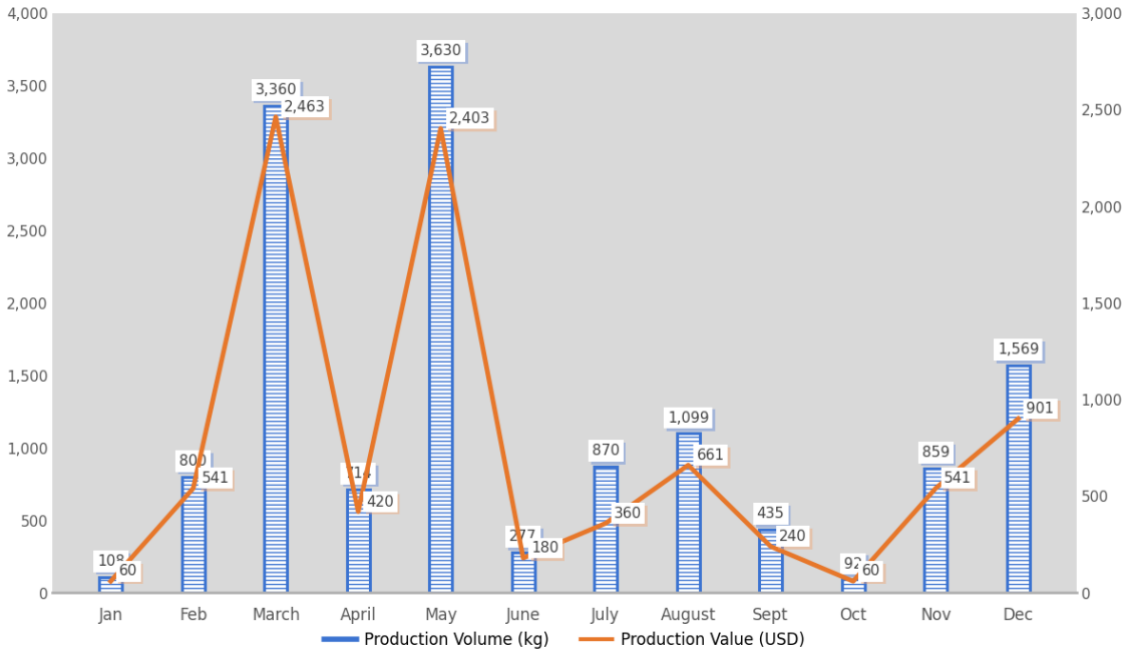

Figure 2. Monthly production volume and production value of *Scomberoides tol* in Sibolga City during 2024.

The graphical pattern demonstrates that fluctuations in production volume are closely mirrored by changes in production value, indicating a strong dependence of economic outcomes on raw material availability. High-production months correspond to sharp increases in total value, while low-production months are associated with markedly reduced revenues. Such patterns are typical of tropical small-scale fisheries, where fishing activity is strongly influenced by seasonal weather conditions, oceanographic variability, and resource availability (Rahim & Hastuti 2023; Yusfiandayani et al 2024).

Seasonal instability in raw material supply has direct implications for the economic performance of salted fish processors. During low-production periods, reduced throughput increases unit processing costs, as fixed costs must be absorbed by smaller production volumes. This condition heightens financial risk, particularly for processors operating within longer and less coordinated supply chains. In contrast, processors embedded in more integrated supply chains demonstrate greater resilience to seasonal fluctuations. Direct relationships with fishers allow these processors to secure more stable access to raw materials, even during periods of reduced landings, thereby maintaining production continuity and moderating revenue declines.

The observed seasonality underscores the importance of supply chain integration as an adaptive strategy in traditional salted fish processing systems. By strengthening coordination between fishers and processors, integrated supply chains reduce exposure to seasonal supply shocks and improve economic stability. This finding reinforces the argument that managing seasonal variability through improved supply chain organization is a key component of economic sustainability in small-scale fisheries-based processing industries.

Financial performance under different supply chain models. The financial feasibility indicators presented in Table 2 reveal substantial differences between the two supply chain models, indicating contrasting levels of economic performance and risk exposure. Supply chain I consistently outperforms supply chain II across all indicators, reflecting a stronger economic position for processors operating within a more integrated structure. These differences highlight not only variations in profitability but also structural disparities in financial resilience.

Rather than merely indicating higher profitability, the superior performance of supply chain I reflects a lower level of economic vulnerability. Lower break-even prices and production volumes, combined with shorter PPs, indicate that processors operating within

integrated supply chains can sustain operations with smaller sales volumes and recover investments more rapidly. These characteristics reduce exposure to fluctuations in raw material availability and market prices, which are inherent in traditional salted fish processing systems that rely on seasonal fish landings and weather-dependent drying methods.

Table 2

Financial performance indicators of *Scomberoides tol* processing under different supply chain models

Supply chain type	*Criteria aspect*					
	Average annual profit (USD)	*Break-even price (USD kg^{-1})*	*Break-even production (BEP, kg)*	Benefit-cost ratio (BCR)	*Payback period (PP, years)*	*Return on investment (ROI, %)*
I	1,182±219	3.34	69.30	2.88	2.25	47.55
II	338±97	7.49	137.70	1.27	3.75	29.87

Values are presented as mean ± SD. Differences in average annual profit between supply chain types were assessed using Welch's two-tailed t-test ($p = 3.31 \times 10^{-6}$). Statistical significance was set at $p < 0.05$.

The relatively low BEP values reflect the cost structure of traditional salted fish processing, where fixed costs remain limited due to the use of simple equipment and small-scale facilities. Under these conditions, the contribution margin per kilogram is relatively high, resulting in a lower break-even output. Importantly, the observed operating volumes of processors exceed the calculated BEP levels, indicating a substantial safety margin and reduced financial vulnerability.

From the perspective of transaction cost theory, these differences can be explained by variations in coordination efficiency and transaction costs. Supply Chain I minimizes search, negotiation, and monitoring costs by reducing intermediary layers and facilitating direct, repeated transactions between processors and downstream market actors. In contrast, the longer structure of Supply Chain II increases transaction costs due to greater information asymmetry, weaker coordination, and higher dependence on intermediaries, which ultimately reduces economic efficiency and increases business risk.

These patterns are further supported by the value chain governance framework proposed by Gereffi et al (2005). The coordination mechanisms observed in Supply Chain I resemble a relational governance structure, characterized by trust-based interactions, repeated exchanges, and mutual dependence among actors. Such governance arrangements enable processors to retain a larger share of value added, improve price transmission, and enhance control over product quality. Conversely, supply chain II exhibits features closer to market-based governance, where limited coordination and reliance on intermediaries dilute value capture and heighten economic vulnerability.

Overall, the analysis demonstrates that supply chain integration enhances financial outcomes not only by increasing profitability but also by reducing transaction costs, lowering exposure to seasonal and market risks, and improving value retention at the processor level. These findings are consistent with broader evidence from fisheries and agri-food value chain studies, which emphasize that shorter and more coordinated supply chains are better positioned to support long-term business viability in small-scale processing systems (Trienekens 2011; Hamilton-Hart & Stringer 2016; Galappaththi et al 2022).

Economic sustainability of the traditional salted fish supply chain. Economic sustainability in traditional salted fish processing extends beyond short-term financial performance and is reflected in the capacity of enterprises to remain economically viable, resilient to seasonal variability, and capable of sustaining livelihoods over time. In small-scale fisheries contexts, sustainability is associated with income continuity, capital recovery, and the ability to cope with environmental and market uncertainty rather than with profitability alone (FAO 2015; Kosamu 2015; FAO 2018a). The findings of this study indicate that supply chain integration is a critical determinant of these sustainability outcomes.

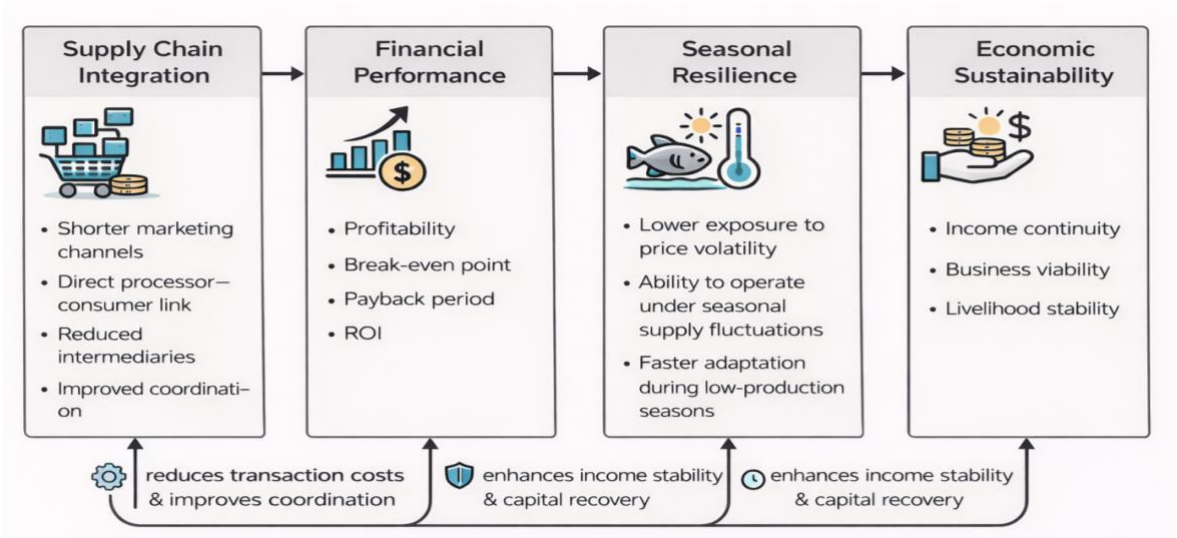

Figure 3. Conceptual framework linking supply chain integration, financial performance, seasonal resilience, and economic sustainability in traditional queenfish salted processing.

To synthesize the empirical findings, Figure 3 illustrates the conceptual framework through which supply chain integration influences financial performance and seasonal resilience, ultimately shaping economic sustainability in traditional salted fish processing systems. Within this framework, integration enhances coordination among actors and reduces transaction costs, thereby strengthening financial outcomes and adaptive capacity.

Processors operating within more integrated supply chains experience more stable access to raw materials, improved price transmission, and reduced reliance on intermediaries. These conditions lower operational uncertainty and support income stability, particularly under fluctuating supply conditions. Conversely, less integrated chains are more exposed to price volatility, information asymmetry, and coordination failures, which constrain long-term business viability.

The traditional characteristics of salted fish processing, marked by simple technology and dependence on sun-drying, heighten sensitivity to seasonal variation in fish landings and weather conditions. In the absence of effective coordination, processors face increased exposure to production interruptions and market instability. Prior studies consistently emphasize that strengthening coordination and market access, rather than replacing traditional practices with capital-intensive technologies, is essential for improving economic resilience in small-scale fisheries-based processing systems (FAO 2015; Kosamu 2015; Galappaththi et al 2022).

Within this context, financial indicators such as profitability, break-even thresholds, PPs, and returns on investment can be interpreted as proxies for economic sustainability when evaluated in relation to risk exposure, capital recovery, and adaptive capacity. Superior financial outcomes observed in integrated supply chains therefore reflect not only greater efficiency, but also an enhanced ability to absorb seasonal shocks and maintain operations during periods of reduced supply or adverse market conditions. Comparable patterns have been reported in fisheries and agri-food value chain studies, which identify coordination as a key mechanism linking financial performance with resilience and long-term sustainability (Trienekens 2011; Stacey et al 2021; Rowan 2023).

Overall, economic sustainability in traditional salted fish processing emerges from the interaction between supply chain integration, financial performance, and resilience to seasonal variability. Integrated organizational structures reduce vulnerability to market and environmental shocks, enabling stable income generation and sustained livelihoods under dynamic operating conditions.

Implications for small-scale fisheries development. The findings of this study demonstrate that improving supply chain integration offers a practical pathway to strengthen the economic sustainability of traditional salted fish processing without undermining local practices. Shorter and more integrated supply chains enable processors to improve efficiency, stabilize income, and enhance competitiveness while continuing to rely on traditional production methods.

From a policy perspective, development strategies should prioritize strengthening coordination among fishers, processors, and traders, facilitating access to markets, and supporting gradual improvements in processing and marketing practices. Such approaches are consistent with the FAO small-scale fisheries guidelines, which emphasize that enhancing value chains and market access is essential for improving economic resilience, food security, and livelihoods in coastal communities (FAO 2015; FAO 2018b). By focusing on integration rather than technological replacement, policy interventions can support sustainable development pathways that respect the cultural and economic foundations of small-scale fisheries.

Conclusions. This study demonstrates that supply chain integration is a key determinant of the economic sustainability of traditional *Scomberoides tol* processing in Sibolga City. Processors operating within more integrated supply chains exhibit stronger financial performance, faster capital recovery, and greater resilience to seasonal fluctuations in raw material availability. These findings indicate that integration enhances not only short-term profitability but also long-term income stability and business viability in small-scale processing systems.

From a policy perspective, the results suggest that efforts to improve economic sustainability should prioritize strengthening coordination among fishers, processors, and market actors, facilitating direct market access, and reducing dependence on intermediaries, rather than promoting capital-intensive technological change. Such strategies align with international recommendations for sustainable small-scale fisheries development that emphasize value chain strengthening and livelihood resilience.

This study is subject to several limitations. Seasonal production patterns were derived from secondary data for a single year, and financial indicators relied partly on self-reported information, which may introduce uncertainty. In addition, the analysis focused primarily on economic aspects and did not explicitly address social or environmental dimensions of sustainability.

Future research should incorporate multi-year production data, expand sustainability assessment to include social and environmental indicators, and explore how institutional support and digital market integration can further enhance resilience in traditional fish processing value chains.

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Conflict of interest. The authors declare that there is no conflict of interest.

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