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## Proposing the Urgency of Consumer Protection Regulations and Freshness Detection Applications for Fish in Traditional Markets Using Technology

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### Abstract

This study explores consumer knowledge and vendor practices related to the freshness of ikan tongkol (*Euthynnus affinis*) in traditional markets in Jember, Indonesia. Using a mixed-methods approach, data were collected from 271 consumers and 62 vendors through surveys and interviews. Consumers mostly relied on sensory indicators like color, smell, and texture—especially color—to assess freshness. Although many felt confident in judging freshness, around 20% were uncertain, revealing a knowledge gap. Social media and the Internet were key information sources, raising concerns about accuracy. Vendors commonly used ice storage, with limited access to refrigeration. Interviews highlighted vendor awareness of quality issues but also challenges due to limited infrastructure. The study reveals a mismatch between perceived and actual freshness, shaped by traditional knowledge and limited objective tools. Enhancing education, vendor practices, and introducing simple freshness indicators could improve transparency, safety, and market resilience. The findings offer insights for policy and food system improvements.

**Keywords:** Fish Freshness Perception; Consumer Knowledge; Traditional Markets; Food Safety Practices; Freshness Detection Technology

## INTRODUCTION

Fish consumption is an essential component of food security, nutritional well-being, and the livelihoods of millions in Indonesia, a country with rich marine biodiversity and vast coastlines. Traditional markets serve as the primary distribution centers for seafood products, particularly for middle- and lower-income consumers who rely on these spaces for daily fresh food. Among the various marine species, *Euthynnus affinis* (commonly known as ikan tongkol) stands out as the most captured fish in the country. According to the 2023 statistics published by the Ministry of Marine Affairs and Fisheries (KKP, 2025b), the production of ikan tongkol reached 738,528 tons, representing the highest output among all fish species and surpassing those of cakalang, tuna, layang, and kembung. Notably, East Java emerged as a key contributor, with a production volume of 568,955 tons. This data, as illustrated in Figure 1, underscores the significant role of regional fisheries production in the national context. The regency of Jember, located in East Java, plays a crucial role in this ecosystem, where fish production supports both nutritional needs and local economic activity, primarily through its network of traditional markets.

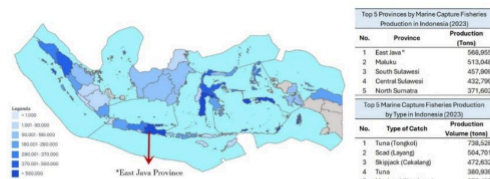


Figure 1. Top 5 Provinces by Marine Capture Fisheries Production and by Type, 2023  
Source: (KKP, 2025b)

Despite the robust production, significant challenges persist in maintaining fish quality, particularly in post-harvest handling, storage, and distribution. One of the most persistent issues is the information asymmetry between sellers and consumers. Research conducted by Hebsale Mallappa et al. (2023) and Verbeke et al. (2005) found that consumers often lack sufficient knowledge to evaluate fish freshness based on objective criteria. Instead, they rely on visual and olfactory cues, which are highly subjective and prone to misinterpretation. Consumers generally associate fish with high nutritional value, mainly due to its omega-3 content, but their awareness of spoilage indicators such as histamine buildup, microbial contamination, or enzymatic degradation remains low (Altintzoglou & Heide, 2016). Furthermore, studies have shown that traditional vendors often share limited information about fish origin, storage conditions, or time since capture, which further impedes informed decision-making at the consumer level (Abdillah et al., 2015; Conte et al., 2014).

From the vendor side, the understanding and implementation of proper cold chain practices and freshness indicators are also frequently inadequate. In a study by (Sari et al., 2024), traditional market vendors in East Java lacked both the infrastructure and training necessary to preserve fish quality beyond several hours, often relying solely on crushed ice without controlled temperatures. Such conditions, particularly in tropical climates like Indonesia's, accelerate fish degradation and histamine production. As a result, vendors inadvertently become agents of foodborne risk, especially when fish is stored or sold over prolonged periods without adequate cooling or monitoring systems.

Fish freshness is a critical parameter in seafood quality and safety, and several studies on Ikan Tongkol have underscored the need for comprehensive strategies to maintain its quality from catch to consumer; for example, Norita et al. (2019) demonstrated that storage at room temperature rapidly accelerates spoilage and histamine formation, while cold and frozen storage conditions significantly extend the sensory acceptability and biochemical integrity of the fish, thereby emphasizing the importance of low-temperature management in curbing bacterial activity, and Purnama et al. (2021) raised concerns regarding environmental contaminants by detecting various microplastics such as fragments and fibers in the digestive tracts of Ikan Tongkol, indicating potential health risks associated with marine pollution; furthermore, chemical safety issues are highlighted by Hananingtyas (2017), who found that a considerable percentage of Ikan Tongkol samples exceeded the permissible limits for heavy metals like lead and cadmium, suggesting that industrial waste has a direct adverse impact on the safety and overall freshness of seafood, and Apriani et al. (2017) contributed to this body of evidence by showing that the time of day influences microbial loads, with morning-harvested fish exhibiting lower contamination levels compared to those sold later in the day, thereby reinforcing that optimized handling practices and proper storage conditions are essential to maintain the organoleptic and nutritional quality of Ikan Tongkol.

Technological advancements globally have made remarkable strides in offering innovative solutions for detecting fish freshness. Several studies have demonstrated the efficacy of non-destructive technologies such as colorimetric sensors, machine vision systems, hyperspectral imaging, and electronic noses. For instance, Khumngern et al. (2024) developed a portable colorimetric sensor capable of detecting amine compounds that indicate spoilage in scombroid fish species. Similarly, Lin et al. (2024) integrated artificial intelligence with imaging technology using models such as VGG19 to assess fish eye clarity and gill color, achieving accuracy levels above 90% in distinguishing fresh from spoiled samples. Additionally, electronic nose devices have been developed to identify volatile organic compounds associated with spoilage, while Torimeters have been commercialized for measuring dielectric properties of fish muscle as an indicator of freshness (Graham et al., 2022).

However, while these technologies have demonstrated strong potential in laboratory or industrial settings, their adoption in traditional markets remains virtually non-existent in Indonesia. This gap is largely due to a lack of policy incentives, limited vendor awareness, high device costs, and inadequate infrastructure at the market level. The lack of integration of these technologies into public health protection frameworks undermines efforts to safeguard consumer well-being. Notably, in the context of East Java, inspections by government agencies are still conducted sporadically through unannounced visits or brief field surveys, which are not sufficient to ensure continuous quality assurance.

The consequences of these systemic weaknesses are not merely theoretical. In April 2020, a significant public health crisis occurred in Jember Regency, East Java, when approximately 250 residents experienced histamine poisoning after consuming *Euthynnus affinis* purchased from local traditional markets (Afifah & Sartika, 2020). Symptoms such as dizziness, rashes, vomiting, and diarrhea were widely reported, prompting concern over food safety monitoring practices. Histamine poisoning, a form of scombroid toxicity, is caused by bacterial decarboxylation of histidine when fish is not properly stored. Norita et al. (2019) emphasized that histamine formation occurs rapidly under conditions typical of traditional wet markets: ambient temperatures, high humidity, and the absence of refrigeration. Such events are not isolated but indicative of a broader national vulnerability in seafood safety.

Furthermore, the economic implications surrounding fish consumption in Jember and broader East Java underline the urgency of addressing quality control failures. According to Disperindag Jatim (2025) and DKP Jawa Timur (2025), the average retail price of ikan tongkol in Jember has nearly doubled between 2020 and 2025, rising from Rp17,687.48 to Rp37,714.29. In contrast, the provincial average rose more moderately from Rp23,895.54 to Rp29,421.16. This data, as illustrated in Figure 2. This discrepancy indicates not only potential inefficiencies in the supply chain but also raises concerns about value-for-money and whether consumers are purchasing fish that aligns with its price and promised quality. Meanwhile, per capita fish consumption data show inconsistent growth in Jember, hovering between 17.7 kg and 19.2 kg per year, whereas East Java overall has exhibited a steadier increase from 22.05 kg to 24.23 kg between 2019 and 2023 (KKP, 2025a). These findings suggest a need to investigate consumer behavior, perceptions of product safety, and the potential deterrent effect of food safety scandals on local consumption patterns.

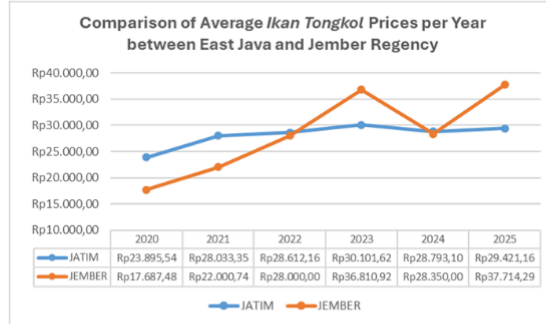


Figure 2. Average Prices Ikan Tongkol 2020 – 2025

This research is therefore driven by an urgent need to bridge the technological, regulatory, and knowledge-based gaps that currently compromise seafood safety in Indonesia's traditional markets. The study aims to evaluate the socio-technical barriers hindering the adoption of freshness detection technologies at the traditional market level; analyze the information asymmetry between fish vendors and consumers; assess public health risks through the lens of past contamination events; and explore policy alternatives for more robust regulatory oversight. By taking Jember as a case study, this research investigates how the intersection of economic, technological, and regulatory factors influences fish quality control in local markets.

The control of freshness and quality detection in traditional markets currently relies solely on sporadic inspections, surprise checks, or field visits by regulators and government agencies. There is no regular mechanism or adoption of technology to consistently protect consumers from low-quality, potentially hazardous fish products in these settings. As such, this research argues for the importance of systemic reforms, including the democratization of freshness detection technologies and the institutionalization of routine quality control mechanisms within traditional markets.

In sum, the convergence of public health concerns, rapid technological advancements, economic disparities, and persistent regulatory inertia necessitates a comprehensive investigation into the state of fish quality control in traditional markets. The findings from this study are expected to contribute meaningfully to academic discourse on food safety, inform policy frameworks, and support practical interventions aimed at improving consumer protection in Indonesia's seafood sector.

## METHOD

<sup>2</sup> This study employs a convergent parallel mixed methods design to investigate disparities in knowledge and practices related to the quality control of *Euthynnus affinis* (ikan tongkol) in traditional markets in Jember, East Java. Quantitative (structured questionnaires) and qualitative (semi-structured interviews) data were collected simultaneously in offline field settings across 10–12 stratified market locations. Participants, consisting of 150–200 consumers and 30–50 vendors, were selected through purposive and convenience sampling. Instruments were adapted from previous research to assess sensory evaluation, negotiation dynamics, and quality control practices. Quantitative data were analyzed descriptively using frequencies, percentages, means, and cross-tabulations, while qualitative data underwent triangulation, member checking, and double coding to ensure credibility. This methodological approach enables a comprehensive understanding of consumer-vendor interactions and challenges in maintaining fish freshness, aligning closely with the research objectives.

## RESULTS AND DISCUSSION

Data were collected over a one-month period (22 February to 23 March 2025) using a mixed-methods approach in central markets of Jember Regency. The study combined quantitative surveys and qualitative interviews. A total of 271 consumer responses were obtained, consisting of 182 via an online Google Form and 89 through in-field administration, while 62 seller responses were collected exclusively in the field. In-depth interviews were conducted with 15 consumers and 12 sellers across ten traditional markets, ensuring a comprehensive view of local trading dynamics.

The consumer profile indicates that the majority of respondents were within the productive age range, with most falling between 41 and 50 years (99 respondents), followed by those aged 31 to 40 (73 respondents) and above 50 (72 respondents). Females greatly predominated, with 243 women compared to 28 men. Most consumers reported a monthly income below 3 million rupiahs (137 respondents) and were primarily high school graduates (168 respondents). The main occupation was homemaking, reported by 177 respondents. In terms of household characteristics, most had a family size of 3 to 5 members (181 respondents). The data reveal that a large proportion of consumers purchased ikan tongkol primarily for household consumption, typically in quantities of less than 1 kilogram per purchase. The majority of respondents, totaling 237 individuals, reported using Android smartphones during market visits. Among these, 187 had sufficient internet data to access online applications. All consumer respondents met the inclusion criteria by being responsible for household food purchases and having made at least three ikan tongkol purchases in the preceding three months.

For sellers, the majority were aged between 41 and 50 years (46,38%) and were predominantly male (58,21%). Most sellers had substantial trading experience, with 71,01% having traded for more than five years. Technological adoption was high among the sellers, as 89,86% reported using smartphones during their trading activities, and 84,06% had internet connectivity. Despite the high level of technological engagement, only 4,35% of sellers had participated in formal training regarding fish freshness standards. All sellers consistently maintained routine sales of ikan tongkol and fulfilled the criterion of having at least one year of trading experience.

### Bridging the Freshness Perception Gap

The study reveals significant knowledge gaps in how consumers assess fish freshness in Jember's traditional markets, a finding that resonates with earlier research (Verbeke et al., 2005; Altintzoglou and Heide, 2016). In a survey of 271 consumers, 806 responses indicated that visual

cues such as color (24.57%) and olfactory cues such as aroma (21.46%) are the primary criteria for judging the freshness of ikan tongkol. Fewer respondents relied on texture (14.52%) or anatomical features like gills and eyes (15.76%), while economic factors such as price (12.28%) and vendor reputation (7.20%) played a secondary role. This substantial reliance on sensory attributes underscores the limitations of subjective evaluations that earlier studies warned could lead to inconsistencies in quality assessments (Viana et al., 2022).

Confidence in determining freshness appears mixed, with 32.1% of consumers very confident and 50.9% somewhat confident, leaving 17.0% unsure. This uncertainty highlights an inherent information asymmetry that is compounded by the prevalent use of digital sources such as the Internet and social media (44.28%) for quality information rather than expert advice or experiential learning (Rodríguez-Salvador & Dopico, 2020). The result is a superficial understanding of key quality indicators, suggesting that enhanced consumer education could bridge these gaps through targeted information campaigns or community workshops.

On the vendor side, 75.81% of 62 respondents rely on ice storage to maintain fish freshness, a method that, while common, is vulnerable to infrastructural deficiencies such as inconsistent ice quality and harsh market conditions (Sari et al., 2024; Wijaya et al., 2024). Qualitative interviews confirmed that vendors adhere to traditional practices, such as timely stock rotation and routine checks, yet acknowledge that these measures are insufficient under extreme environmental challenges. One vendor described placing fish on crushed ice and inspecting them every hour, a routine that, despite its diligence, fails to provide the consistency necessary for consumers to reliably assess freshness.

Qualitative narratives from consumers further illustrate the gap. Several recounted incidents where fish that appeared fresh based on color and smell later exhibited off odors and soft textures after cooking, leading to post-purchase dissatisfaction. These experiences confirm that sensory evaluations, while essential, are not foolproof and call for the integration of objective quality indicators. Both consumer and vendor perspectives converge on the urgent need for modern interventions to provide standardized measures of freshness and reduce market uncertainty.

In summary, the findings clearly demonstrate a dual challenge: consumers rely predominantly on subjective sensory cues yet remain uncertain about their accuracy, while vendors depend on traditional preservation methods that are prone to environmental and logistical issues. This knowledge gap highlights the necessity for enhanced consumer education, improved preservation infrastructure, and innovative technological solutions to introduce objective measures for quality assurance. Such interventions are critical to narrowing the discrepancy between perceived and actual fish freshness (Krešić et al., 2022), ultimately improving food safety and market efficiency in Jember's traditional seafood supply chain.

#### **Negotiation Dynamics in Traditional Seafood Markets**

The findings reveal that price bargaining is an integral part of the consumer experience in traditional markets in Jember, with fish freshness serving as a key lever in negotiations. Quantitative data indicate that 86% of consumers reported regularly negotiating prices when purchasing ikan tongkol. Among these, nearly 91% stated that they use the fish's perceived freshness as a bargaining tool. These figures support the introduction's assertion that consumer behavior is heavily influenced by sensory evaluations, as demonstrated in earlier studies (Altintzoglou & Heide, 2016; Verbeke et al., 2005).

Consumers indicated that freshness significantly affects market value; when rating the influence of freshness on price, 47% strongly agreed and 36% agreed. This consensus confirms that sensory indicators such as color, smell, and texture underpin the valuation process, thereby reflecting the information asymmetry highlighted by Rodríguez-Salvador & Dopico (2020). The gap is further emphasized by the fact that many consumers, despite showing moderate confidence in their own assessments of fish freshness, use their uncertainties to negotiate prices and mitigate perceived risk.

Qualitative interviews enrich the quantitative picture. Consumers frequently cited deviations in texture or an off-odor as valid reasons to ask for a discount. In one account, a respondent recalled negotiating a lower price after noticing that the fish was not as firm as expected. Other respondents mentioned that an off-odor triggered their negotiation efforts when compared with fresher batches. Vendors reported a range of responses. Approximately 92% of vendors



confirmed that they regularly encounter price negotiations, though reactions vary considerably. Some vendors described explaining their quality control and storage processes in detail and offering only minor discounts when customers complained about freshness issues. One vendor noted that when confronted with a freshness complaint, he offered a 5% discount while emphasizing his routine practice of storing fish on crushed ice. This approach reflects a tendency to defend product quality verbally rather than conceding on price immediately.

Overall, the results underscore a complex dynamic between consumers and vendors centered on fish freshness. Consumers rely primarily on subjective sensory judgments, a pattern consistent with previous literature (Altintzoglou & Heide, 2016; Pieniak et al., 2013), while vendors depend on traditional practices to support their pricing. The variation in vendor responses suggests that sellers face challenges in reconciling consumer expectations with the limitations of their preservation methods. These findings reinforce the need for interventions such as consumer education and the adoption of objective freshness detection tools, as advanced by recent technological studies (Khumngern et al., 2024; Lin et al., 2024). The integration of such measures could improve transparency and foster a fairer pricing system, ultimately enhancing both consumer satisfaction and vendor profitability, as well as bridging the knowledge gap in the seafood market of Jember, East Java.

#### Emerging Perspectives on Technology-Based Quality Assurance

The quantitative data indicate that consumers in Jember overwhelmingly support the adoption of technology for verifying the freshness of ikan tongkol in traditional markets. An impressive 93.1% of respondents affirm the need for an objective tool to assess fish freshness. In addition, 58.4% expressed willingness to pay a premium for fish with technology-verified quality, although a notable group of 19.2% stated that their willingness depended on cost. These findings reiterate the concerns raised in the introduction and literature review regarding the limitations of subjective sensory methods such as color, smell, and texture for quality assessment (Altintzoglou & Heide, 2016; Pieniak et al., 2013; Verbeke et al., 2005). Consumers are aware of the inconsistencies inherent in traditional evaluations and view technological solutions as a promising remedy that could mitigate information asymmetry, as previously observed by Rodriguez-Salvador and Dopico (2020).

Qualitative interviews reinforce the quantitative trends by revealing a strong consumer optimism about technology-based quality assessments. Many consumers expressed that an accurate, data-driven tool would enhance their confidence in the fish they purchase. One respondent noted in Indonesian, "Saya melihat teknologi sebagai alat yang sangat berguna untuk mengukur kesegaran secara objektif," emphasizing the potential for technology to supplement or replace subjective evaluation methods. Despite this enthusiasm, some consumers expressed reservations regarding potential extra costs and emphasized that affordability and user-friendliness are key to widespread adoption. These sentiments parallel findings from earlier studies, which indicate that while consumers value objective quality markers, practical considerations such as cost-effectiveness remain critical determinants in the acceptance of new technologies (Altintzoglou & Heide, 2016; Pieniak et al., 2013; Verbeke et al., 2005).

In contrast, the attitude among vendors is more cautious and reflects the operational and economic challenges they face. Although only 17.7% of vendors initially agreed that advanced technology should be implemented in traditional markets, 70% indicated they would adopt such technology if it were both affordable and easy to use. Qualitative data from vendor interviews underscore this tension; several vendors acknowledged that digital systems to monitor storage conditions and record catch times could improve quality control and market reputation. However, many are reluctant to abandon established traditional methods without clear evidence of benefits and support in training and infrastructure. This complex perspective underscores the need for integrated interventions that combine technological innovation with capacity building and regulatory backing. Such collaborative efforts can help bridge the gap between consumer expectations and vendor practices while enhancing food safety and market transparency, as emphasized throughout the literature (Khumngern et al., 2024; Lin et al., 2024).

Overall, the findings demonstrate a strong consumer desire for objective verification of fish freshness and a conditional openness among vendors toward technology adoption. Addressing vendors' concerns about cost, ease of integration, and training requirements will be essential in

fostering a modern, transparent quality control system. In doing so, the integration of objective, technology-based methods holds promise for narrowing the persistent knowledge gaps in fish freshness assessment that have long been a concern in traditional markets in Indonesia.

#### Modernizing Quality Control Practices in Traditional Seafood Markets

The combined quantitative and qualitative data provide a comprehensive picture of the quality control practices and challenges experienced in traditional markets in Jember. Consumers reported that while most purchase ikan tongkol on a monthly basis, a significant number buy the fish weekly. A majority of consumers (77.8%) rely on fixed traditional market stalls, yet mobile vendors still contribute to the supply chain. These results resonate with earlier literature that emphasizes the central role of sensory evaluations in these market environments (Verbeke et al., 2005; Altintozglou and Heide, 2016), while also highlighting situational factors that influence purchasing decisions.

Consumer feedback reveals an increasing demand for improvements in quality control. Many consumers voiced a strong desire for an independent certification system to objectively verify fish freshness at the point of sale. Respondents recommended regular inspections by third-party authorities and the implementation of digital systems that record catch times and monitor storage conditions in real time. Such suggestions mirror concerns previously discussed in the literature regarding the limitations of relying solely on subjective indicators like color, smell, and texture (Apriani et al., 2017; Pianusa et al., 2016; Rodriguez-Salvador & Dopico, 2020). In addition, consumers advocated for enhanced storage infrastructure, including modern refrigeration systems, to replace the inconsistent quality of ice that is predominantly used at many market stalls.

From the vendors' perspective, the challenges in maintaining fish freshness are primarily related to external and infrastructural factors. Quantitative data indicate that 44.1% of vendors depend on distant markets and 29.4% rely on wholesalers, while only 17.6% source their fish from local fishermen. This complex supply chain likely contributes to freshness issues due to delays in transportation. The greatest challenge cited by vendors was high ambient temperature, which 58.7% of respondents identified as the primary factor undermining freshness. Additional challenges included the cost of ice, the lack of refrigeration, and limited storage space. These operational difficulties are consistent with earlier studies that have documented similar barriers in traditional markets (Roiska et al., 2024; Wijaya et al., 2024).

Qualitative interviews with vendors provide further detail on these challenges. Vendors consistently mentioned that extreme heat and outdated market infrastructure force them to rely on ice storage as the main preservation method. Many described daily struggles such as poor-quality ice and delayed replenishment during peak hours, conditions that compromise the quality of fish and feed into consumer skepticism. Vendors also recounted how frequent power outages and limited stall space further reduce their capacity to adopt even modest improvements. In responding to consumer queries about fish freshness, vendors tend to combine verbal assurances with visual cues, such as displaying catch times and arranging fish neatly on fresh ice. However, these traditional methods often fall short of meeting the evolving expectations of consumers who are increasingly aware of objective quality measures.

The divergence between consumer expectations and vendor practices underscores the need for multi-faceted interventions. Consumers are eager for objective methods that confirm fish freshness and help overcome the inherent information asymmetry that has long plagued the traditional seafood market (Conte et al., 2014; Viana et al., 2022). On the other hand, vendors are constrained by infrastructural limitations and external market pressures that hinder the adoption of modern quality control techniques. The qualitative data suggest that while vendors are aware of the potential benefits of technological improvements such as digital monitoring systems, they are hesitant to invest in these solutions without clear assurances regarding affordability and ease of use.

In conclusion, the evidence clearly illustrates that while consumers depend predominantly on subjective sensory indicators to judge fish freshness, the traditional storage methods used by vendors, primarily ice storage under challenging environmental conditions, result in inconsistent quality. Both consumers and vendors recognize the potential benefits of integrating objective technological solutions, yet there remain substantial logistical and economic hurdles to overcome. Addressing these issues may require a combination of improved market infrastructure, enhanced



training programs, and stronger regulatory support. Such comprehensive initiatives can help bridge the quality control gap, enhance consumer trust, and ultimately lead to a more stable and transparent seafood supply chain in Jember, East Java. This integrated approach reflects the broader themes discussed in both the introduction and literature review and underscores the urgent need for modernization in quality control practices in traditional markets.

## CONCLUSION

This study provides a concise yet comprehensive examination of quality control and negotiation in the sale of ikan tongkol in traditional markets in Jember. The findings reveal substantial knowledge gaps, complex price negotiation behaviors, divergent attitudes toward technological solutions, and operational challenges in preserving fish freshness. Consumers rely heavily on visual and olfactory cues to assess fish quality but remain uncertain due to the absence of standardized guidelines. At the same time, vendors continue to depend on traditional ice storage methods, which struggle under harsh environmental conditions and infrastructural limitations. Price negotiations often center on perceptions of freshness; while consumers frequently use freshness deviations as bargaining tools, vendors attempt to counterbalance concerns through verbal assurances and established routines. Attitudes toward technological interventions further illustrate a divergence between consumers and vendors. Although over 93% of consumers support and are even willing to pay a premium for objective freshness verification, vendors express cautious openness only when technologies are both affordable and user-friendly. This underscores the need for interventions that combine modern technology with enhanced infrastructure and targeted training. Addressing the identified challenges in quality control practices requires a multifaceted approach. Future initiatives should focus on developing cost-effective, user-friendly technological solutions, strengthening market infrastructure, and implementing robust regulatory oversight. Such strategies would not only reduce uncertainty and improve food safety but also enhance overall market efficiency in Indonesia's traditional seafood supply chain.

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