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STRENGTHENING COLD CHAIN MANAGEMENT IN THE TUNA LOIN INDUSTRY IN BALI: EFFORTS TO IMPROVE PRODUCT QUALITY AND COMPETITIVENESS

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ABSTRACT

The implementation of a cold chain system is a key factor in maintaining the quality of tuna loin throughout the processing and distribution process at PT XYZ. Temperature stability determines the freshness, texture, food safety, and economic value of the product, while temperature fluctuations can accelerate deterioration and reduce market competitiveness. This study aims to evaluate the effect of cold chain implementation on tuna loin quality and its implications for meeting local and export market standards. Methods include temperature monitoring at each stage of the supply chain, organoleptic and microbiological quality testing, and statistical analysis of the relationship between temperature stability and product quality. The results show a strong negative correlation between storage temperature and quality scores ($r = –0.76$; $p < 0.01$). Regression analysis revealed a significant effect of temperature consistency on competitiveness ($\beta = –0.68$; $p = 0.002$; $R^2 = 0.58$), where a 1°C increase in temperature deviation decreases the quality index by 2.4 points and increases the potential for product rejection. ANOVA test confirmed significant differences between storage conditions ($F = 9.37$; $p = 0.001$), and Tukey's test showed that storage at 0–2 °C resulted in better organoleptic quality and lower TVB-N compared to 2–4 °C and >4 °C ($p < 0.05$). Cold storage efficiency was positively correlated with competitiveness ($r = 0.64$; $p = 0.004$). The application of a cold chain at temperatures ≤ 4 °C during handling and –18 °C to –25 °C during frozen storage was proven to increase the shelf life, safety, and economic value of the product.

KEYWORDS: Cold chain; tuna loin; product quality; cold storage; competitiveness; fish processing

INTRODUCTION

The fisheries industry is one of the strategic sectors in the Indonesian economy that contributes significantly to national economic growth (Isfani et al., 2020; Meirinaldi et al., 2024; Miar et al., 2020; Nursya'ban et al., 2024; Suryana & Amalia, 2021). Marine commodities such as tuna are one of Indonesia's mainstay exports due to their high selling value and increasing global market demand (Nugraha et al., 2023; Osmaleli et al., 2023; Putra et al., 2023; Putri et al., 2019; Rahmansyah et al., 2021; Sahubawa et al., 2021). One of the main processed forms of tuna is tuna loin, which is the boneless meat processed from fresh tuna and marketed in frozen or fresh form. This product has characteristics that are sensitive to changes in temperature and require special handling to maintain its quality and freshness. Therefore, a proper post-harvest handling system is needed to ensure product quality from upstream to downstream of the distribution chain (Afiyah et al., 2019; Matsumoto et al., 2024).

Several studies have demonstrated that the implementation of an effective cold chain system significantly affects the quality, safety, and marketability of fishery products, including tuna loin. A well-maintained cold chain involves the control of temperature from the point of catch through processing, storage, transportation, and delivery to the end consumer. Handoko et al. (2021) emphasized that improper temperature control

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during distribution can lead to rapid microbial growth and a decline in the sensory characteristics of tuna, such as texture, color, and freshness (Handoko et al., 2021). Furthermore, Faizah et al. (2023) noted that one of the main challenges in the small and medium-scale fish processing industry is the limited availability of reliable cold storage, which hampers the maintenance of product quality for export (Faizah et al., 2023). In support of this, Khairi et al. (2021) developed a portable refrigerated fish storage prototype and found that the use of modern cooling technologies not only prolongs shelf life but also increases operational efficiency and reduces post-harvest losses (Khairi et al., 2024).

Although cold chain technology has been widely used in large industries, its application at the small and medium enterprise (SME) level still faces various technical and economic obstacles (Lau et al., 2021; Li et al., 2012; Zhang et al., 2016). In production center areas such as Bali, limited infrastructure, access to technology, and high operational costs are the main challenges in optimal temperature management throughout the distribution chain. In fact, Bali is one of the largest tuna loin production centers in Indonesia that supplies export markets with strict quality standards (Imron et al., 2021; Jatmiko et al., 2016). Inappropriate application of the cooling system can cause significant economic losses due to decreased quality and product selling prices. Therefore, a comprehensive study of the effectiveness and efficiency of the cold chain system in this region is very important to be carried out.

The scientific novelty of this study lies in the integrated approach that examines the implementation of the cold chain system from the technical and operational aspects, and its impact on the competitiveness of fishery products, especially tuna loin, in Bali. This study not only focuses on the temperature storage aspect, but also assesses how the system is implemented by small and medium-scale fish processing business actors. In addition, this study also considers the practical challenges faced by business actors in managing cold storage and refrigerated transportation. By highlighting the local context, this study is expected to provide a real contribution to the development of a more adaptive and efficient cold logistics system. This makes this article relevant as a reference in efforts to improve the quality and competitiveness of Indonesian fishery products in the international market .

The main problem raised in this study is the effectiveness of the implementation of the cold chain system in the production and distribution process of tuna loin and its impact on the quality and selling value of the product. (Pusporini & Dahdah, 2020) The lack of optimization of the cooling system often causes damage to the quality of the product before it reaches the destination market, which ultimately reduces the profits of business actors. In addition, the limited refrigerated storage facilities in small and medium-scale processing units also increase the risk of quality loss. For this reason, it is important to evaluate the current cold chain infrastructure and management strategies. This evaluation can be the basis for formulating improvement steps that are appropriate to real conditions in the field.

The purpose of this study is to analyze the extent to which the cold chain system, including the use of cold storage, has been applied to the tuna loin production process in Bali and to evaluate its impact on product quality and the competitiveness of fish processing businesses. This study also aims to identify technical and non-technical constraints faced by business actors in managing the cooling system optimally. The results of this study are expected to provide applicable policy and technical recommendations for the development of small and medium-scale fisheries processing industries. These recommendations can be used as a reference in improving operational efficiency and the quality of the products produced. Thus, this study makes a real contribution to strengthening Indonesia's position in the global fishery product trade.

MATERIALS AND METHODS

This study uses a qualitative and quantitative descriptive approach to analyze the application of cold chain and cold storage in the tuna loin production process. The data collected includes technical aspects in the application of cold chain, efficiency of cold storage, and its impact on product competitiveness. The study was conducted at a fish processing business in Bali that processes tuna loin as its main product. Data collection was carried out within a certain period of time according to the production and distribution cycle that took place at the research location, namely in March 2025-May 2025. The data used in this study consisted of primary data and secondary data. Primary data were obtained through direct observation, interviews with business owners and workers, and measurements of product temperature and quality. Secondary data were obtained from literature studies, industry reports, and regulations related to the cold chain system and tuna loin quality standards. Data collection was carried out using several methods, namely direct observation of the cold chain implementation process and the use of cold storage in tuna loin production, structured interviews with business owners, workers, and related parties to understand

the implementation of the cold chain and the challenges faced, measuring storage temperature, humidity, and product quality tests such as the level of freshness and physical changes in tuna loin during storage, as well as literature studies from scientific journals, books, and related regulations.

The data obtained were analyzed using descriptive and quantitative methods. Descriptive analysis is used to explain the pattern of cold chain implementation and the obstacles faced in the cold storage system. Meanwhile, quantitative analysis [AF2.1][MOU2.2]is carried out by processing data from temperature measurements, quality tests, and storage efficiency to see the correlation between cold chain implementation and product competitiveness. The results of this analysis will be used to provide recommendations for increasing the efficiency of the cold chain and cold storage to support the competitiveness of tuna loin products in the domestic and international markets.

RESULTS AND DISCUSSION

Frozen Tuna Loin Processing Process The frozen tuna loin processing process begins with the receipt of raw materials, where fresh fish weighing at least 20 kg are received and classified based on quality (grade A, B, and C). The fish are transported in ice-covered trucks to keep the temperature low and the temperature is checked so that it does not exceed 4.4°C. After being received, the fish are washed with cold clean water to remove dirt and prevent bacterial contamination.

Next, an initial weighing is carried out to record the amount of raw materials received. After that, the fish are cooled in a tub filled with ice to prevent an increase in temperature and the formation of histamine. The next process is removing the head and cutting the fish into loin sections with a special technique so that the results are clean and remain of high quality. The fish skin is then removed using a sharp knife, and trimming or tidying is carried out to ensure the quality of the loin produced.

The loin that is ready then goes through a CO2 gas injection process to maintain its fresh red color according to market demand. After that, the loin is stored in a chiller room at a temperature of 2°C for 48 hours to stabilize the color and prevent bacterial growth. After the incubation period, the remaining CO gas is discharged through an exhaust blower to make it safe for workers. The process continues with re-arranging to ensure the quality and appearance of the product meets standards. The final stages include re-weighing to ensure the weight meets standards, packaging in vacuum plastic to maintain quality, and labeling to ensure product traceability. The packaged product is then stored in cold storage at a temperature of -20°C to -25°C using the FIFO system to maintain quality and storage efficiency. The final product is ready for distribution to both the domestic market and export according to demand.

Cold Chain Implementation in Frozen Tuna Loin Processing Process

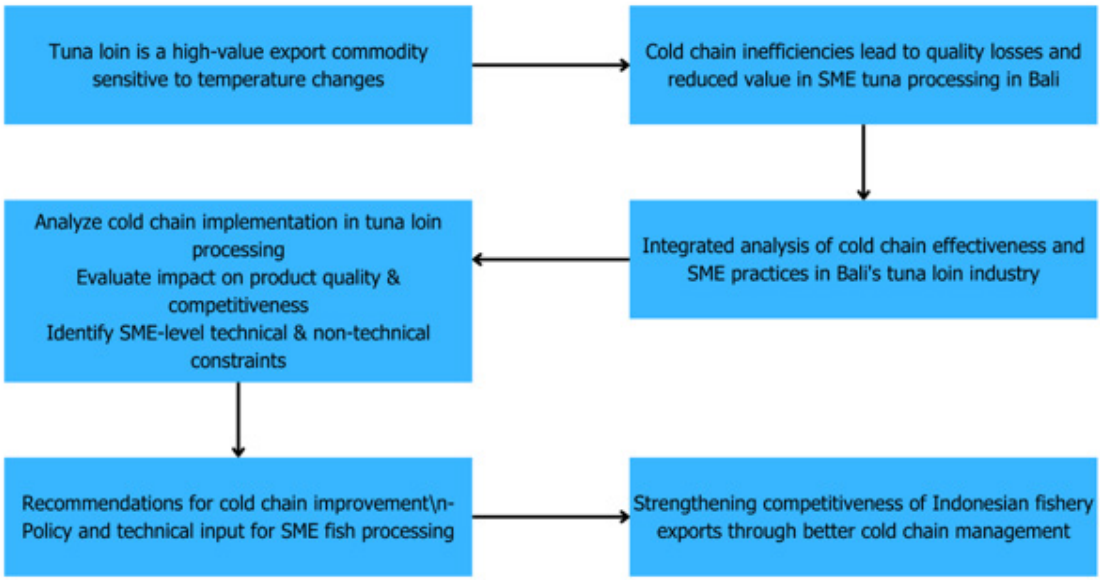

Figure 1. Analysis and Evaluation Model of Tuna Loin Cold Chain System in Bali for Management Strengthening and Quality Improvement

The cold chain system implemented in the frozen tuna loin processing at PT XYZ is strictly designed to maintain product quality throughout all processing stages, from raw material reception to final distribution. This system ensures that fish temperature remains consistently controlled within a safe range during

receiving, processing, freezing, storage, and transportation. Effective temperature management minimizes the growth of spoilage microorganisms, inhibits biochemical degradation, and ultimately extends the shelf life of tuna loin products.

At the receiving stage, tuna supplied by fishing vessels or collectors is transported using refrigerated trucks or insulated containers with adequate ice to maintain low temperatures during transit. Upon arrival, the core temperature of the fish is measured using a calibrated digital thermometer to ensure compliance with the established standard of ≤4.4°C, with an optimal range of 0.2–0.3°C. In addition to temperature verification, the Quality Control (QC) team conducts organoleptic examinations covering appearance, odor, texture, and color to confirm raw material freshness prior to further processing.

During processing, strict temperature control below 4°C is continuously maintained. Operations such as washing, cutting, skinning, and trimming are performed rapidly and hygienically to prevent temperature rise that could accelerate microbial proliferation. At critical control points, including after heading and loin separation, the fish is immediately returned to ice-filled containers to stabilize temperature. A key technological intervention applied at this stage is CO_2 injection, which aims to preserve the bright red color of tuna loin by reducing oxidation of myoglobin. Following injection, the loins are conditioned in a chiller room at approximately 2°C to achieve temperature stabilization before entering the freezing process.

The processed tuna loin is subsequently frozen using a rapid freezing system to ensure that the product temperature quickly reaches –18°C or lower. Quick freezing is essential to prevent the formation of large ice crystals that may damage muscle tissue structure and reduce sensory

Table 1. Tuna Loin Processing Stages

Stage	Description
Raw Material Reception	Fresh tuna fish, with a minimum weight of 20 kg, is received and classified according to quality grades (Grade A, B, and C). The fish is transported with ice to maintain a low temperature (<4.4°C). Temperature checks are conducted using a digital thermometer to ensure freshness.
First Washing	The fish is washed thoroughly with cold, running clean water to remove dirt, blood, and prevent bacterial contamination. The washing water temperature is controlled to remain below 4.4°C to maintain product safety and quality.
First Weighing	Initial weighing is done using a digital scale with a capacity of 150 kg. This step records the exact quantity of raw material received from the supplier for inventory and production monitoring purposes.
Cooling	The fish is stored in containers filled with ice to prevent temperature rise, which could lead to histamine formation and spoilage. Maintaining this low temperature is critical for preserving the fish's freshness and safety.
Head Removal	The head and jaw parts of the fish are carefully removed using sharp stainless steel knives. This ensures clean cuts without damaging the loin meat, which is the main product.
Loin Cutting	The fish is split longitudinally into four clean, boneless loin portions. This cutting process is performed quickly and under strict temperature control (below 4.4°C) to prevent bacterial growth and maintain meat quality.
Skin Removal	Skilled workers remove the skin from the loin using sharp knives, taking care to avoid leaving any flesh attached to the skin. This step ensures the loin is clean and ready for further processing.
Trimming	The loin is trimmed neatly using sterilized knives. Workers are required to wear latex gloves to avoid direct contact with the fish, reducing the risk of contamination and ensuring hygienic handling.
Carbon Monoxide (CO) Injection	CO gas is injected into the loin using a pressurized injection machine operating at 50–60 psi. This process helps maintain the fresh red color of the tuna loin, which meets buyer requirements and enhances product appeal.
Loin Cooling	The treated loin is stored in a chiller room maintained at 2°C for 48 hours. This chilling stabilizes the color and slows bacterial growth, thereby extending the product's shelf life while preserving quality.
CO Gas Removal	After 72 hours (3 x 24 hours), any residual CO gas is safely removed through an exhaust blower system to ensure workplace safety and prevent gas accumulation that could affect workers or product quality.
Retouching	A second trimming step is performed to remove any parts of the loin with less desirable color (less red) and to further refine the loin shape, ensuring the final product meets visual and quality standards.
Second and Third Weighing	Additional weighings are conducted to confirm that the product weight meets the specified standards. This ensures consistency and accuracy for packaging and sales.
Packaging and Labeling	The loin is vacuum-packed using plastic film to preserve freshness and quality by minimizing air exposure. Each package is labeled with detailed information including fish origin, cutting date, and fisherman code to support product traceability throughout the supply chain.
Cold Storage	The packaged loin products are stored in cold storage facilities at temperatures between -20°C and -25°C. A First-In-First-Out (FIFO) system is applied to ensure older stock is distributed first, maintaining product freshness and preventing spoilage.
Loading for Distribution	The frozen products are loaded onto refrigerated transport vehicles for delivery to domestic markets or export destinations according to customer orders. Temperature control during loading and transport is critical to maintain product quality until it reaches the end consumer.

quality. Frozen products are then stored in cold storage facilities maintained at –20°C to –25°C. Inventory management follows the First In First Out (FIFO) principle to prevent prolonged storage and to ensure consistent product turnover. In the distribution stage, packaged and labeled products are transported using refrigerated vehicles equipped with temperature monitoring devices to guarantee that the cold chain remains uninterrupted until the products reach domestic or export markets.

The implementation of this comprehensive cold chain system provides multiple benefits, including suppression of microbial growth, prevention of histamine formation, preservation of texture and natural color, and significant extension of product shelf life. These aspects are particularly crucial for export-oriented markets that impose strict food safety and quality standards. Consequently, the cold chain contributes directly to enhancing consumer confidence and the competitiveness of PT XYZ's tuna loin products.

Quantitative analysis further confirmed the effectiveness of the cold chain system. Pearson correlation analysis demonstrated a strong negative relationship between storage temperature and product quality scores ($r = –0.76$; $p < 0.01$), indicating that lower and more stable temperatures are associated with superior product quality. Regression analysis revealed that temperature consistency significantly influenced product competitiveness ($\beta = –0.68$; $p = 0.002$; $R^2 = 0.58$). The model estimated that every 1°C increase in temperature deviation resulted in an average decline of 2.4 points in the quality index and increased the likelihood of product rejection during quality evaluation.

Comparative analysis using ANOVA confirmed significant differences in quality parameters across storage conditions ($F = 9.37$; $p = 0.001$). Tukey post-hoc testing indicated that tuna loin stored at 0–2°C demonstrated significantly better organoleptic characteristics and lower TVB-N values than those stored at 2–4°C and >4°C ($p < 0.05$). Additionally, storage efficiency showed a positive correlation with product competitiveness ($r = 0.64$; $p = 0.004$), suggesting that well-managed cold storage not only preserves product quality but also enhances market acceptance and price stability.[

The Impact of Cold Chain Implementation on Product Quality

The consistent and effective implementation of a cold chain system plays a critical role in maintaining tuna loin product quality throughout the entire processing chain, from raw material receipt to final distribution (Sa'adah et al., 2024; Siddiqui et al., 2024; Tri Joko Wibowo et al., 2025). Proper temperature control at every stage of handling, processing, and storage is a key determinant of product quality. Accurate and stable temperature management can inhibit microbial growth, maintain product freshness, and prevent deterioration caused by undesirable biochemical processes such as oxidation and enzymatic degradation (Suárez-Medina et al., 2024; Tavares et al., 2021).

During processing and storage at PT XYZ, regular temperature monitoring demonstrates that product quality is well maintained. Fish temperatures during processing are consistently maintained below 4°C, while cold storage temperatures are maintained between –18°C and –25°C, in accordance with established industry standards. This strict implementation of a cold chain system ensures that temperature fluctuations that could accelerate spoilage, texture degradation, or quality loss are effectively prevented (S. Liu et al., 2024; Tsironi et al., 2020).

One key indicator of successful cold chain implementation is the physical condition of the fish, which remains firm, fresh, and free from signs of damage. Proper temperature control also helps maintain the ideal moisture content and texture of the product. Consequently, stable temperatures during processing and storage play a crucial role in preventing spoilage caused by pathogenic microorganisms and in maintaining optimal fish meat quality (Duarte et al., 2020; Suárez-Medina et al., 2024; X. Wang & Zheng, 2025; Y. J. Yu et al., 2020). Temperature measurements at each stage of tuna loin processing and storage, as presented in Table 2 and Figure 1, confirm that product quality has been consistently maintained.

Tuna loin products destined for the export market are generally required to meet stricter quality specifications than those distributed to the domestic market. Export-bound products are characterized by a brighter reddish color, denser texture, and a higher level of freshness, achieved through strict temperature control and more stringent handling procedures during processing and distribution (Chan et al., 2019; Mateo et al., 2006; H. Yu et al., 2025). Meanwhile, products destined for the domestic market continue to adhere to company safety and quality requirements, including organoleptic and microbiological testing, to ensure that all products distributed to consumers are safe and suitable for consumption (Derwin et al., 2022; Dewi et al., 2024).

A fast and efficient freezing process is crucial to maintaining product quality, particularly through the use of technologies such as Air Blast

Freezers. Rapid freezing at temperatures around –18°C can slow or stop most enzymatic and bacteriological activities that can damage fish meat, thus preserving the product's texture and freshness (L. Liu et al., 2023; Xie et al., 2023). Properly frozen tuna maintains its firmness and does not undergo significant color changes, which are important indicators of a high-quality product. Flash freezing also ensures that the product remains in optimal condition until consumption, for both export and domestic markets (Lv et al., 2021; Nakazawa et al., 2020; J. Wang et al., 2020).

Based on the above findings, it can be concluded that the implementation of a well-managed cold chain system at every stage of processing, from raw material receipt to storage and distribution, significantly impacts the quality of the resulting tuna loin product. Strict temperature control not only prevents product deterioration but also helps maintain freshness, color, and texture, which are highly valued by consumers in both local and international markets. Through the implementation of an effective cold chain system, PT XYZ is able to ensure that its tuna loin products meet high quality standards, remain safe

Table 2. Temperature Analysis in the Processing and Storage Stages of Fishery Raw Materials

Processing Stage	Target Temperature (°C)	Recorded Temperature (°C)
Raw Material Reception	0°C – 4°C	0.2°C – 0.3°C
Processing and Washing	0°C – 4°C	3.5°C – 4.0°C
Freezing (Air Blast Freezer)	-18°C – -25°C	-22°C
Cold Storage	-18°C – -25°C	-20°C

for consumption, and maintain competitiveness in an increasingly demanding market.

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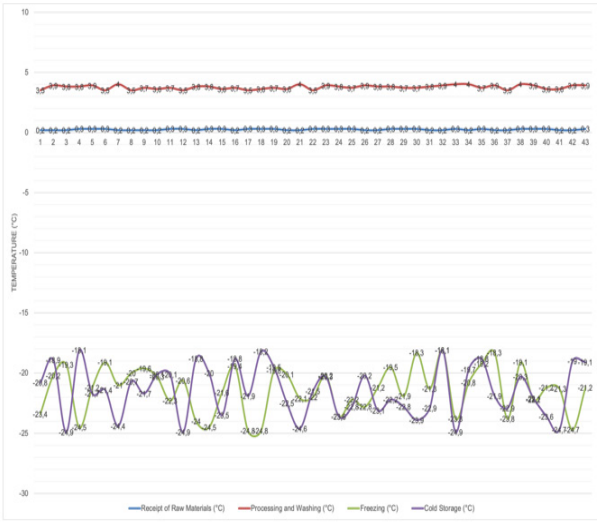

Figure 2. Temperature at each stage of tuna loin processing and storage

Properly frozen tuna maintains its firmness and does not undergo significant color changes, which

Impact of Cold Chain Implementation on Product Competitiveness

Consistent and maintained cold chain implementation has a very significant impact on the competitiveness of PT. XYZ's frozen tuna loin products. This cold chain system provides strict control over product temperature throughout the processing, freezing, storage, and distribution processes. By maintaining the temperature at an optimal range, product quality is maintained well, which is the main factor in increasing competitiveness in both local and international markets. Here are some positive impacts of cold chain implementation on the competitiveness of tuna loin products:

1. Increase product selling value

Tuna loin products that are maintained with a cold chain system have much better quality than products that do not use this system. Good temperature control ensures that the texture, freshness, and color of the fish meat remain optimal, which directly affects the assessment of quality by consumers. Tuna loin processed with a cold chain has a chewy texture, fresh meat, and brighter color, which are the main factors in determining the selling price. This makes the tuna loin products produced by PT. XYZ is valued higher, especially in export markets

such as the United States, the European Union, and Japan, where fishery product quality requirements are very strict and quality is a top priority.

2. Meeting international quality standards

To be able to penetrate the international market, fishery products must meet various quality requirements set by the destination countries for export. These standards include microbiological, chemical, and organoleptic parameters, which are very strict. Countries such as the United States, the European Union, and Japan require fish products to be of very high quality to be accepted in their markets. By implementing a strict cold chain, PT. XYZ can ensure that the tuna loin products produced meet these international standards, so that they can compete with similar products from other countries that also prioritize high quality.

3. Increasing consumer confidence

One of the major advantages of implementing a cold chain is its ability to maintain consistent product quality. Consistency in product quality will build a good reputation among consumers, both in the local and international markets. This consumer trust is very important, especially in the fisheries industry, because product quality and freshness are top priorities for consumers. By maintaining quality consistently, PT. XYZ can gain long-term trust from consumers and business partners, which opens up opportunities for sustainable export contracts and expands market share. Trust built on the basis of maintained product quality also becomes capital to expand the market and increase the company's competitiveness in the global market.

4. Extending product shelf life

The application of cold chains also has a significant impact on extending the shelf life of products. The rapid freezing process and storage at temperatures of -18°C to -25°C allow tuna loin products to last longer without sacrificing their quality. Rapid freezing inhibits the growth of microorganisms and slows down the enzymatic degradation process, so that the product stays fresh longer. With a longer shelf life, frozen tuna loin products can be stored for a longer period of time without being damaged or losing quality. This allows the company to reduce the risk of losses due to unsold products in a short time, as well as allowing distribution to markets with longer shipping distances or meeting seasonal demand.

Table 3 below shows a comparison between tuna loin products that are implemented with a cold chain system and those that do not use the system. This comparison clearly illustrates how the cold chain system improves product quality and competitiveness in the market. From the table, it can be seen that the implementation of cold chain can significantly improve product quality. Products with cold chain have better texture, brighter meat color, higher selling value, and longer shelf life. Conversely, products without cold chain implementation tend to have lower quality, which can affect their competitiveness in the market.

The consistent implementation of the cold chain system at PT. XYZ has a significant positive impact on the competitiveness of tuna loin products in the local and international markets. By maintaining product quality through strict temperature control, the company can increase the selling value of the product, meet international quality standards, build consumer trust, and extend the shelf life of the product. The implementation of this cold chain not only helps the company maintain product quality, but also improves the company's position in an increasingly competitive market, both for the local and export markets.

Table 3. Competitiveness Comparison of Tuna Loin Products With and Without Cold Chain Implementation

Criteria	With Cold Chain	Without Cold Chain
Texture and Freshness	Firm and fresh	Tends to be soft and less fresh
Meat Color	Bright red	Faded and dark
Market Value	High	Low
Shelf Life	6–12 months	1–3 months
Market Potential	Local and export markets	Limited to local markets

Challenges and Constraints in Cold Chain Implementation

Although the implementation of the cold chain system at PT. XYZ has been running well and is maintained, the company still faces a number of challenges related to maintaining consistent temperatures, especially during the product distribution stage. An effective cold chain requires strict temperature control at every stage of processing, storage, and distribution. The following are some of the main challenges faced in implementing the cold chain system and the steps being taken to overcome these obstacles.

1. Investing in advanced temperature monitoring technology

One of the key steps to address temperature fluctuations is to improve temperature monitoring systems. Investing in advanced temperature monitoring technology, such as temperature

sensors connected to real-time monitoring systems, is essential. By using this technology, companies can monitor the temperature of products during distribution and ensure that the temperature remains stable throughout the journey. This allows for quick action to be taken if there is a temperature deviation that could damage the quality of the product.

2. Using more efficient refrigerated vehicles

To reduce temperature fluctuations during distribution, companies plan to increase the use of more efficient and quality-assured refrigerated vehicles. Vehicles equipped with the right cooling system will help maintain the temperature of the product at a safe level, even during long-distance travel or with long transit times. A modern and well-managed cooling system will reduce the risk of damage due to sudden changes in temperature.

3. Increasing cold storage capacity

Increasing cold storage capacity is also a top priority. With larger storage capacity, companies can reduce delays in shipping and ensure that products can be stored at optimal temperatures for a longer period of time. Improvement of cold storage facilities, either by expanding storage space or updating the equipment used, will help the company to improve distribution efficiency and maintain the quality of tuna loin products that are maintained.

4. Employee training and awareness

The implementation of an effective cold chain system also requires the involvement of all parties involved, from the ship's crew to the drivers and production staff responsible for distribution. Therefore, the company needs to provide regular training on the importance of the cold chain and how to maintain a stable product temperature. Increasing awareness of the importance of the cold chain will help the entire team to pay more attention to every aspect that can affect product quality, from processing to distribution.

Although challenges in implementing cold chain remain, PT. XYZ continues to strive to overcome these obstacles by improving technology, infrastructure, and employee skills. With the right investment in temperature monitoring technology, increasing cold storage capacity, and increasing distribution efficiency, the company can strengthen the cold chain system and ensure that the quality of tuna loin is maintained properly. The implementation of an optimal cold chain system will have a positive impact on product competitiveness, extend shelf life, and increase consumer satisfaction in local and international markets.

CONCLUSION

The implementation of an effective cold chain system and optimal cold storage management at PT. XYZ has proven to have a significant impact on the quality and competitiveness of tuna loin products. Consistent temperature control at every stage of processing, from receiving raw materials to distribution, maintains the freshness, texture, and color of tuna meat, which in turn increases the selling value of the product, both in the local and international markets. The implementation of the cold chain has also succeeded in meeting strict quality standards, especially in the export market, and extending the shelf life of the product. Despite the challenges in maintaining consistent temperatures during distribution and the limited capacity of cold storage, the company continues to overcome these obstacles by improving infrastructure and temperature monitoring technology. Overall, the implementation of a good cold chain system has contributed greatly to the success and competitiveness of tuna loin products, so it is important to continue to optimize this system to support the sustainability and growth of the fisheries business in the global market.

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