Fisheries Journal, 16 (2), 997-1008 (2026)
http://doi.org/10.29303/jp.v16i2.2206

QUALITY ASSURANCE OF FROZEN CENTER CUT LOIN IN MEETING NATIONAL STANDARDS AND EXPORT REQUIREMENTS AT XYZ COMPANY IN BALI

Jaminan Mutu Loin Center Cut Beku dalam Memenuhi Standar Nasional dan Persyaratan Ekspor Pada Perusahaan XYZ di Bali

I Gusti Ayu Budiadnyani[1], I Made Aditya Nugraha[2*], I Gede Riyan Mahayana[1]

[1]Department of Marine Product Processing, Marine and Fisheries Polytechnic of Jembrana
[2]Department of Fisheries Mechanization, Marine and Fisheries Polytechnic of Kupang

Kampung Baru Pelabuhan Ferry Street, West Kupang 85351, Kupang, East Nusa Tenggara

* Correspondence email: made.nugraha@kkp.go.id

(Received May 1st 2026; Accepted June 3rd 2026)

ABSTRACT

This study aims to assess the quality of frozen loin center cut products in relation to the Indonesian National Standard (SNI) and export requirements, considering the increasing demand for quality and food safety in international markets. A descriptive quantitative approach was employed through direct observation, interviews, and analysis of primary and secondary data collected from a fish processing industry in Bali. Quality evaluation was conducted based on organoleptic, chemical, and microbiological parameters. The results indicate that the production process was carried out systematically by implementing proper fish handling practices, including a consistent cold chain system and appropriate stock management. Organoleptic assessment showed that the product had excellent quality with a high level of freshness. Chemical analysis revealed low histamine levels in both raw materials and final products, indicating effective temperature control and handling during processing. Microbiological testing demonstrated that total plate counts and pathogenic bacteria such as Escherichia coli and Salmonella spp. were within acceptable limits, confirming good sanitation and hygiene practices. Overall, the evaluated parameters comply with SNI and export standards, indicating that the product is safe and suitable for international markets. However, histamine content and microbiological contamination remain critical factors that require strict control to ensure consistent product quality. This study highlights the importance of maintaining cold chain integrity, sanitation, and quality control systems to enhance competitiveness in the global seafood market.

Keywords: cold chain system, food safety, histamine, microbiological quality, quality control

ABSTRAK

Penelitian ini bertujuan untuk menilai kualitas potongan tengah loin beku dalam kaitannya dengan Standar Nasional Indonesia (SNI) dan persyaratan ekspor. Penelitian ini menggunakan pendekatan kuantitatif deskriptif melalui observasi langsung, wawancara, dan analisis data

primer dan sekunder yang diperoleh langsung di industri perikanan di Bali. Evaluasi kualitas dilakukan berdasarkan parameter organoleptik, kimia, dan mikrobiologis. Hasil penelitian menunjukkan bahwa proses produksi dilakukan secara teratur dengan menerapkan praktik penanganan ikan yang tepat, termasuk sistem rantai dingin yang konsisten dan manajemen stok yang sesuai. Penilaian organoleptik menunjukkan kualitas produk yang sangat baik dengan karakteristik kesegaran yang tinggi. Analisis kimia mengungkapkan kadar histamin yang rendah baik pada bahan baku maupun produk akhir, menunjukkan pengendalian suhu dan penanganan yang tepat selama pemrosesan. Pengujian mikrobiologis menunjukkan bahwa jumlah total koloni dan bakteri patogen seperti *Escherichia coli* dan *Salmonella spp*. berada dalam batas yang dapat diterima, menegaskan praktik sanitasi dan higiene yang baik. Secara keseluruhan, parameter yang dievaluasi sesuai dengan SNI dan standar ekspor, menunjukkan bahwa produk tersebut aman dan cocok untuk pasar internasional. Namun, kandungan histamin dan kontaminasi mikrobiologis tetap menjadi faktor kritis yang memerlukan pengendalian ketat untuk memastikan kualitas produk yang konsisten. Studi ini menyoroti pentingnya menjaga integritas rantai dingin, sanitasi, dan sistem pengendalian mutu untuk mendukung daya saing produk di pasar makanan laut global.

Kata kunci: histamin, mikrobiologis, keamanan pangan, kualitas, sistem rantai dingin

INTRODUCTION

Fishery products, particularly tuna, are among the leading commodities with high economic value and play an important role in international trade (Purimahua & Tupamahu, 2022; Tidd et al., 2018). One of the most preferred processed tuna products is frozen loin, especially the center cut, due to its uniform meat quality, boneless structure, and flexibility for further processing according to industrial and consumer needs (Nugraha et al., 2026; Suryono et al., 2023; Zalukhu et al., 2023). Frozen tuna loin is a product that has undergone cutting, removal of bones, dark meat, and skin, followed by freezing until the core temperature reaches -18°C to maintain freshness and extend shelf life. Proper freezing processes are crucial as they directly affect the stability of product quality during storage and distribution (Dung et al., 2016; Utari, 2023).

Global market demand for frozen center cut loin products continues to increase in line with the rising consumption of seafood-based products and the development of the modern food industry. This condition requires fish processing industries to produce products that are not only of high quality but also comply with strict food safety standards (Dewi et al., 2024; Nugraha et al., 2026; Sayuti et al., 2023; Wartini et al., 2024; Zalukhu et al., 2023). The quality of frozen center cut loin products is determined by various parameters, including physical aspects such as color, texture, and appearance; chemical aspects such as moisture, protein, fat content, and freshness indicators; and microbiological aspects related to food safety and consumption feasibility. These three aspects serve as the main indicators in determining product eligibility, especially for export markets that impose stricter standards (Esteves & Aníbal, 2021; Franceschelli et al., 2021; Kontominas et al., 2021; Prabhakar et al., 2020; Zalukhu et al., 2023).

In the context of international trade, fishery products intended for export must comply with applicable quality standards, including the Indonesian National Standards (SNI) as the domestic reference and the requirements of importing countries, which generally refer to international standards. Compliance with these standards is a key factor in maintaining product competitiveness in the global market. Products that fail to meet these requirements may face rejection in destination countries, resulting in economic losses and reduced trust in Indonesian fishery products (Indrotristanto et al., 2023; Mursit et al., 2022; Nugroho et al., 2022; Resnia

et al., 2016; Suseno & Suadi, 2021). Therefore, the implementation of a strict and sustainable quality control system is essential in the fish processing industry.

Periodic product quality evaluation is a strategic approach to ensure that the products meet established standards. This activity not only guarantees product safety and quality but also serves as a means of process control, efficiency improvement, and prevention of potential quality deviations. Through comprehensive evaluation of physical, chemical, and microbiological parameters, industries can identify weaknesses in production processes and implement continuous improvements to enhance overall product quality.

As international market demands for safe, high-quality, and competitive products continue to increase, studies on the quality of frozen center cut loin products are essential. This study aims to analyze and evaluate the conformity of frozen center cut loin quality based on physical, chemical, and microbiological parameters with the Indonesian National Standards (SNI) and export requirements. Furthermore, this research seeks to determine the extent to which the products meet the applicable standards and to provide insights into potential improvements in processing practices to enhance overall product quality.

The expected benefits of this study include both theoretical and practical contributions. Theoretically, the findings can serve as a scientific reference for the development of knowledge in fish processing, particularly in quality evaluation of frozen products based on national and international standards. Practically, this study is expected to provide valuable input for fish processing industries in improving quality control systems, maintaining product consistency, and meeting export market requirements. In addition, the results may contribute to enhancing the competitiveness of Indonesian fishery products in the global market and strengthening the confidence of importing countries in the quality of the products.

METHODS

This study employed a descriptive quantitative approach aimed at assessing the quality of frozen center cut loin products based on physical, chemical, and microbiological parameters, as well as evaluating their compliance with the Indonesian National Standards (SNI) and export requirements. The research was conducted over a period of two months (March–April 2026) in a fish processing industry unit in Bali. This approach was chosen because it provides a systematic, factual, and accurate description of product quality conditions and their level of compliance with applicable standards.

Data collection in this study consisted of primary and secondary data. Primary data were obtained directly through observation, interviews, and active participation in the production process. Observations were carried out by directly examining all stages of frozen center cut loin production, starting from raw material reception to the final product, including quality control at each stage. In addition, observations included product quality parameters such as organoleptic testing, histamine levels, and sanitation and hygiene conditions during the production process. Interviews were conducted with relevant personnel, including production workers, supervisors, and quality control and quality assurance (QC and QA) staff, to obtain in-depth information regarding processing systems, applied quality standards, and challenges in meeting export requirements. Meanwhile, active participation involved direct involvement in production and quality testing activities, allowing the researcher to gain a practical understanding of processing flow, handling techniques, and factors influencing product quality.

Secondary data were obtained through documentation and literature studies. Documentation studies involved collecting company records of product quality testing, including organoleptic data, histamine levels, and microbiological test results for both raw materials and final products. Literature studies were conducted by reviewing various scientific sources such as journals, books, research reports, and relevant standards, including SNI for fresh fish and frozen tuna loin, as well as quality requirements from importing countries. These

secondary data served as comparative and supporting information in analyzing field research findings.

Data processing was carried out by organizing and simplifying the collected data to facilitate analysis and interpretation. Quantitative data, such as organoleptic test results, histamine levels, and microbiological data, were processed using simple statistical methods. Organoleptic values were calculated to obtain mean values and confidence ranges, while histamine data were analyzed using average calculations. Microbiological data were analyzed based on available test results and compared with applicable standards. All processed data were then systematically presented in an informative report format.

Data analysis was conducted using a descriptive quantitative method by presenting numerical data and interpreting them systematically. The analysis focused on three main aspects: the quality characteristics of frozen center cut loin products, their compliance with Indonesian National Standards (SNI) and export requirements, and the identification of quality parameters that potentially act as limiting factors in meeting export standards. The test results were compared with relevant SNI standards, such as those for fresh fish and frozen tuna loin, as well as with maximum limits established by importing countries. Through this analysis, the level of product compliance and factors requiring improvement to enhance quality and competitiveness in international markets could be identified.

RESULTS

The results of the study indicate that the production process of frozen center cut loin is carried out through several integrated main stages, starting from raw material reception, temporary storage, head cutting, loin formation, carbon monoxide (CO) treatment, chilled storage, trimming and cutting into center cut portions, vacuum packaging, freezing using an air blast freezer, metal detection, packaging and labeling, frozen storage, and loading. All production stages are conducted sequentially by applying the cold chain principle and the First in First Out (FIFO) system to maintain the quality of both raw materials and products throughout the process (Figure 1).

The quality characteristics of raw materials and final frozen center cut loin products were determined based on organoleptic, chemical, and microbiological analyses. The organoleptic test results showed that both raw materials and final products had an average score of 9, indicating excellent quality in terms of appearance, color, texture, and aroma (Table 1). Chemical analysis of histamine levels showed that the raw materials ranged from <2.50 to 2.78 ppm, while the final products ranged from <2.50 to 9.29 ppm (Table 2). Meanwhile, microbiological testing indicated that the Total Plate Count (TPC) values were 3.7×10^3 CFU/g in raw materials and 6.6×10^3 CFU/g in the final products. Other microbiological parameters, such as Escherichia coli and coliform, showed values of <3 MPN/g, while Salmonella spp. was not detected in both raw materials and final products (Table 3).

The evaluation of quality compliance demonstrated that all tested parameters, including organoleptic attributes, histamine levels, and microbiological quality, were below the maximum limits established by the Indonesian National Standards (SNI) and export requirements (Table 4). Therefore, the frozen center cut loin products meet the applicable quality standards and are suitable for export markets. Furthermore, based on the identification of quality parameters, histamine levels and microbiological aspects were identified as critical factors requiring special attention, as they have the potential to become limiting factors in meeting export quality standards if not properly controlled during production and distribution processes.

Table 1. Organoleptic test results of raw materials and final products

Observation	Raw Material Organoleptic Score	Final Product Organoleptic Score
1	9	9
2	9	9
3	9	9
Average	9	9

Table 2. Histamine content test results of raw materials and final products

Sample Type	Sample No.	Test Result (ppm or mg/kg)	Company Standard (ppm or mg/kg)	SNI Standard (ppm or mg/kg)
Raw Material	1	<2.50	17	100
	2	0,1375	17	100
	3	<2.50	17	100
Final Product	1	9.29	30	100
	2	6.56	30	100
	3	<2.50	30	100

Table 3. Microbiological test results of raw materials and final products

Sample Type	Total Plate Count (CFU/g)	*E. coli* (MPN/g)	Coliform (MPN/g)	*Salmonella spp.*
Raw Material	3.7×10^3	<3	<3	Negative
Final Product	6.6×10^3	<3	<3	Negative
Company Standard	5.0×10^5	<3	<3	Negative
SNI Standard	5.0×10^5	<3	<3	Negative

Table 4. Quality compliance of center cut loin with indonesian national standards (sni) and export requirements

Quality Parameter	Test Result	Company Standard	SNI Standard
Raw Material			
Organoleptic (Raw Material)	8	7	7
Histamine (Raw Material)	<2.5 ppm	17 ppm	100 ppm
Total Plate Count (CFU/g)	3.7×10^3	5.0×10^5	5.0×10^5
E. coli (MPN/g)	<3	<3	<3
Coliform (MPN/g)	<3	<3	<3
Salmonella spp.	Negative	Negative	Negative
Final Product			
Organoleptic (Final Product)	8	7	7
Histamine (Final Product)	6.56 ppm	30 ppm	100 ppm
Total Plate Count (CFU/g)	6.6×10^3	5.0×10^5	5.0×10^5
E. coli (MPN/g)	<3	<3	<3
Coliform (MPN/g)	<3	<3	<3
Salmonella spp.	Negative	Negative	Negative

Figure 1. Frozen Center Cut Loin Production Process Flow

DISCUSSION

Frozen Center Cut Loin Production Process

Observations of the frozen center cut loin production process demonstrate that all stages are carried out systematically and in an integrated manner, adhering to the principles of good fishery product processing. The production process begins with the receipt of raw materials, consisting of fresh tuna that has undergone an initial cleaning process, followed by a series of handling and processing steps until the final product is ready for export. At the raw material receipt stage, initial quality control is conducted through organoleptic testing, temperature measurements, and sampling for chemical analysis (histamine). This stage is critical because the quality of the raw materials significantly determines the quality of the final product.

The raw materials are then temporarily stored in refrigerated conditions before being decapitated and the loin is formed. The loin formation process involves separating the meat from the bones, skin, and dark meat, aiming to obtain high-quality meat. This stage is followed by a carbon monoxide (CO2) treatment to maintain the tuna's bright red color and maintain its visual appeal. After the CO2 treatment, the product is stored in a refrigerated chamber at a controlled temperature to maintain quality stability before entering the further trimming stage, where the center cut is formed to the specified size and weight.

The next stage is vacuum packaging, which removes air from the packaging, thus inhibiting oxidation and microbial growth. The product is then frozen using an air blast freezer

at ultra-low temperatures to accelerate the freezing process and maintain product quality. After freezing, metal detection is performed to ensure there is no foreign material contamination, a crucial part of the food safety assurance system. Products that have passed inspection are then packaged, labeled according to export regulations, and stored in cold storage at freezing temperatures before being loaded into refrigerated containers.

This entire process demonstrates the consistent implementation of a cold chain system, from raw material receipt to distribution, which plays a crucial role in maintaining low product temperatures to inhibit enzymatic activity and microbial growth. Furthermore, the implementation of a First in First Out (FIFO) system during cold and frozen storage demonstrates sound inventory management to maintain freshness and prevent quality degradation due to prolonged storage. In terms of quality control, each production stage is monitored by Quality Control (QC) and Quality Assurance (QA) departments, thereby minimizing the potential for quality deviations.

Although there are several differences from the process flow listed in the SNI standard for frozen tuna loin, such as the absence of a weeding stage because the raw materials have been weeded beforehand, and the incorporation of several quality sorting stages in the production process, overall the process implemented has reflected the implementation of Good Fish Processing Practices (CPIB). This shows that the production system implemented has been able to support the achievement of product quality that meets national standards and export requirements, both in terms of quality, food safety, and product consistency.

Quality Characteristics of Frozen Center Cut Loin

Quality test results indicate that frozen center cut loin exhibits excellent quality in terms of organoleptic, chemical, and microbiological aspects, which are the main indicators in assessing fishery product quality. For organoleptic aspects, a high average value (near the maximum value) indicates excellent sensory characteristics, including bright and distinctive meat color, a dense and elastic texture, and a fresh aroma without any indication of spoilage. This reflects optimal freshness of the raw materials used and consistent handling from start to finish. High organoleptic values also indicate no physical damage or quality degradation during processing, including cutting, washing, additional treatments, and freezing.

From a chemical perspective, the observed parameter, histamine levels, showed relatively low values in both the raw materials and the final product. Histamine is a biogenic compound formed by bacterial activity on the amino acid histidine and is often used as an indicator of the freshness and safety of fish products, particularly scombroid fish like tuna (Biji et al., 2016; Madejska et al., 2022; Mercogliano & Santonicola, 2019). The low histamine levels in the raw materials indicate that post-harvest handling was carried out promptly and appropriately, particularly in maintaining a low temperature of the fish from capture to receipt at the processing unit. Meanwhile, the histamine levels in the final product remained within the safe range, indicating that there was no significant increase during the production process that could compromise food safety. This indicates that the cold chain system was implemented effectively and was able to inhibit the activity of histamine-forming bacteria during processing and storage.

From a microbiological perspective, test results showed that the Total Plate Count (TPL) values for both the raw materials and the final product were well below the established maximum limit, indicating that the level of microbial contamination was still low and the product was fit for consumption. Furthermore, specific microbiological parameters, such as Escherichia coli, coliform, and Salmonella spp., met the requirements, with no pathogenic bacteria found that could harm consumer health. This reflects the effective implementation of sanitation and hygiene throughout the production process, including cleanliness of equipment, the work environment, and employee hygiene practices.

Despite this, test results indicated a slight increase in microbiological values from raw materials to the final product. This increase likely occurred due to product contact with equipment, work surfaces, or the environment during processing, such as during the cutting, trimming, and packaging stages. However, this increase was within acceptable limits and did not affect the overall product quality or safety. This indicates that despite the potential for cross-contamination during production, the implemented quality control system was able to maintain low levels of microbiological contamination.

Overall, the quality characteristics of the frozen center cut loin produced indicated a high and stable product quality, both in terms of appearance, chemical composition, and microbiological safety. This reflects that the raw material handling, processing, and implemented quality control system were effective in maintaining product quality in accordance with established standards.

Quality Conformity with National Standards and Export Requirements

Based on the evaluation of quality parameters, including organoleptic, chemical, and microbiological aspects, it was found that all tested indicators met the requirements stipulated in the Indonesian National Standard (SNI) and applicable export market regulations. This conformity indicates that the frozen center cut loin product meets a quality level acceptable nationally and internationally. The SNI standard is used as a basic reference for ensuring the quality and safety of fishery products domestically, while export requirements generally refer to stricter standards related to food safety, particularly those set by the export destination country.

In terms of organoleptic aspects, high scores indicate that the product meets the required quality criteria, such as distinctive color, good texture, and fresh aroma. These parameters are important because they directly relate to consumer acceptance of the product (Antão-Geraldes et al., 2020; Esteves & Aníbal, 2021; Sarastani et al., 2023). From a chemical perspective, histamine levels well below the established maximum limit indicate that the product is safe for consumption and does not pose a risk of scombroid poisoning. This reflects that the raw material handling process, particularly in maintaining temperature and handling time, has been carried out optimally, thus inhibiting the activity of histamine-forming bacteria. Furthermore, the stability of histamine levels from raw materials to the final product also indicates that there were no significant deviations in storage or processing conditions during the production process.

From a microbiological perspective, test results indicate that the Total Plate Count (TPC) and indicator microbial parameters, such as Escherichia coli, coliform, and Salmonella spp., met the maximum limits set by the quality standards. The absence of pathogenic bacteria such as Salmonella spp. is an important indicator that the product is safe for consumption and has undergone hygienic processing. The low microbiological contamination values also indicate that sanitation and hygiene practices in the production environment have been implemented effectively, including cleanliness of equipment, process water, and workforce practices that comply with standard operating procedures.

This quality compliance with national standards and export requirements also reflects the effectiveness of the quality control system implemented in the production process. This system encompasses supervision at every stage of production, from raw material selection and temperature control, processing, to product storage and distribution. The implementation of quality assurance systems such as Good Fish Processing Practices (GMP) and supervision by Quality Control (QC) and Quality Assurance (QA) departments plays a crucial role in ensuring that every product meets established standards.

Meeting these quality standards has significant implications for product competitiveness in the international market. Export destination countries generally impose strict requirements

on food products entering their territories, so products that do not meet these standards are potentially rejected or subject to sanctions. Therefore, the ability to consistently produce products that meet standards is a key factor in maintaining export sustainability. Furthermore, consistent quality also plays a role in building trust and a product's reputation in the eyes of importing countries.

Therefore, the evaluation results indicate that the frozen center cut loin product meets applicable quality standards and has a strong potential for acceptance in the global market. This compliance not only reflects good product quality but also demonstrates the industry's readiness to meet the demands of an increasingly competitive and food safety-oriented international market.

Quality Parameters as Limiting Factors in Fulfilling Export Requirements

Although the evaluation results indicate that the general quality of frozen center cut loin products meets national standards and export requirements, several parameters, particularly histamine levels and microbiological parameters, could potentially be limiting factors in consistently meeting these standards. These two parameters are highly sensitive to changes in handling and processing conditions, requiring strict and ongoing control. In the context of international trade, failure to control these parameters can result in product rejection, recalls, and even market access restrictions by export destination countries.

Histamine levels are a key indicator in assessing the quality and safety of fishery products, particularly tuna, a member of the scombroid group. Histamine is formed through the decarboxylation of the amino acid histidine by enzymes produced by certain bacteria. This process is significantly influenced by the temperature and handling time of the raw material. If fish are not immediately handled at low temperatures after capture, the activity of histamine-forming bacteria will increase significantly, leading to histamine accumulation in the fish's flesh. Therefore, consistent implementation of the cold chain system is a key factor in preventing histamine formation. Any temperature fluctuations, whether during catching, transportation, receiving raw materials, or during processing, have the potential to significantly increase histamine levels. Furthermore, histamine is heat-stable and cannot be eliminated through subsequent processing, including freezing. This makes histamine a critical parameter that must be controlled from the beginning of the production chain (Adams et al., 2018; Altafini et al., 2022; McCarthy et al., 2015).

On the other hand, microbiological parameters are also important limiting factors because they are directly related to hygiene and sanitation aspects of the production process. Microbiological contamination can originate from various sources, such as raw materials, water used in the process, production equipment, work surfaces, and labor (Cortés-Sánchez et al., 2025; Dumen et al., 2020). Although test results indicate that microbiological values are still within safe limits, an increase in values from raw materials to the final product indicates the potential for cross-contamination during processing. This contamination can occur at critical stages such as cutting, trimming, washing, and packaging, especially if sanitation procedures are not optimally implemented.

Furthermore, production environmental factors such as air quality, floor cleanliness, and drainage systems can also affect the level of microbial contamination in products. Worker behavior and awareness regarding personal hygiene, such as the use of personal protective equipment, handwashing habits, and adherence to standard operating procedures, also play a crucial role in preventing contamination. Therefore, controlling microbiological parameters is not a single factor but rather the result of integrating various aspects of the production system (Akdemir Evrendilek, 2026; Yadav et al., 2025).

To minimize the risk of failure to meet export standards, strengthening the implementation of a comprehensive quality assurance system is necessary. This includes strict

temperature control at every stage of the process, increasing the effectiveness of sanitation and hygiene, and conducting regular training for workers on good processing practices. Furthermore, regular supervision and monitoring by Quality Control (QC) and Quality Assurance (QA) departments need to be strengthened, especially at critical points that have the potential to cause quality deviations. The implementation of a risk-based system such as Hazard Analysis and Critical Control Points (HACCP) is also a strategic step in identifying, controlling, and monitoring critical points in the production process.

Therefore, even though the product generally meets established quality standards, special attention to controlling histamine levels and microbiological parameters is still necessary to ensure consistent product quality. Optimal management of these two parameters will be crucial for success in maintaining access to export markets and increasing the competitiveness of fishery products at the global level.

CONCLUSION

Based on the research and discussion, it can be concluded that the frozen center cut loin production process was carried out systematically and structured, applying the principles of good fishery product processing. All production stages, from raw material receipt to storage and distribution of the final product, employed a cold chain system and proper storage management, thereby maintaining the quality of the raw materials and product throughout the process. The quality characteristics of the resulting frozen center cut loin demonstrated excellent quality based on organoleptic, chemical, and microbiological parameters. High organoleptic values reflect the freshness of the raw materials and the accuracy of the processing process, while low histamine levels indicate optimal temperature control and raw material handling. Furthermore, microbiological contamination values, which were below the threshold, indicate that sanitation and hygiene practices were implemented during the production process, making the product safe for consumption. The quality conformity evaluation results indicated that all tested parameters met the Indonesian National Standard (SNI) and applicable export requirements. This demonstrates that the implemented quality control system is effective in producing a quality product that is competitive in the international market. Thus, the resulting frozen center cut loin product is suitable for global marketing. However, several quality parameters, namely histamine levels and microbiological parameters, have the potential to be limiting factors in meeting export standards. These two parameters are significantly influenced by the consistency of cold chain, sanitation, and hygiene practices throughout the production process. Therefore, strict and continuous control of these two aspects is essential to maintain consistent product quality and minimize the risk of rejection in the export market.

ACKNOWLEDGEMENT

Thank you to the Ministry of Marine Affairs and Fisheries for all the support that has been given.

REFERENCES

Adams, F., Nolte, F., Colton, J., Debeer, J., & Weddig, L. (2018). Precooking As A Control for Histamine Formation During The Processing of Tuna: An Industrial Process Validation. *Journal of Food Protection*, *81*(3), 444–455. https://doi.org/10.4315/0362-028X.JFP-17-276.

Akdemir Evrendilek, G. (2026). The Hygiene Continuum in Seafood Processing: Integrating Design, Sanitation, and Workforce Safety for Sustainable Food Systems. *Hygiene*, *6*(1), 6. https://doi.org/10.3390/hygiene6010006.

Altafini, A., Roncada, P., Guerrini, A., Sonfack, G. M., Accurso, D., & Caprai, E. (2022). Development of Histamine in Fresh and Canned Tuna Steaks Stored Under Different

Experimental Temperature Conditions. *Foods*, *11*(24), 4034. https://doi.org/10.3390/foods11244034.

Antão-Geraldes, A. M., Hungulo, S. R., Pereira, E., Teixeira, A., Teixeira, A., & Rodrigues, S. (2020). Sensory Quality and Consumers' Acceptance Towards Wild and Farmed Brown-Trout (*Salmo trutta*) and Farmed Rainbow-Trout (*Oncorhynchus mykiss*). *Brazilian Journal of Food Technology*, *23*, e2019104. https://doi.org/10.1590/1981-6723.10419.

Biji, K. B., Ravishankar, C. N., Venkateswarlu, R., Mohan, C. O., & Gopal, T. K. S. (2016). Biogenic Amines in Seafood: A Review. *Journal of Food Science and Technology*, *53*(5), 2210–2218. https://doi.org/10.1007/s13197-016-2224-x.

Cortés-Sánchez, A. D. J., Diaz-Ramírez, M., Rayas-Amor, A. A., Espinosa-Chaurand, L. D., Torres-Ochoa, E., & Salgado-Cruz, M. D. la P. (2025). Microbiological Hazards in The Food Chain of Fish and Products, A Focus on *Klebsiella* spp. *Veterinary Sciences*, *12*(2), 133. https://doi.org/10.3390/vetsci12020133.

Dewi, J., Sayuti, M., & Salampessy, R. B. S. (2024). Quality Testing of Frozen Loin Tuna (*Thunnus albacares*). *Indonesian Journal of Aquaculture Medium*, *4*(3), 106–113. https://doi.org/10.29303/mediaakuakultur.v4i3.3892.

Dumen, E., Ekici, G., Ergin, S., & Bayrakal, G. M. (2020). Presence of Foodborne Pathogens in Seafood and Risk Ranking for Pathogens. *Foodborne Pathogens and Disease*, *17*(9), 541–546. https://doi.org/10.1089/fpd.2019.2753.

Dung, T. N., Khang, D. T., & Vu, L. A. (2016). Effects of Extraction Methods and Storage Conditions on Histamine Content in Frozen Tuna (*Thunnus albacares*). *Can Tho University Journal of Science*, *4*, 63–70. https://doi.org/10.22144/ctu.jen.2016.044.

Esteves, E., & Aníbal, J. (2021). Sensory Evaluation of Seafood Freshness Using The Quality Index Method: A Meta-Analysis. *International Journal of Food Microbiology*, *337*, 108934. https://doi.org/10.1016/j.ijfoodmicro.2020.108934.

Franceschelli, L., Berardinelli, A., Dabbou, S., Ragni, L., & Tartagni, M. (2021). Sensing Technology for Fish Freshness and Safety: A Review. *Sensors (Switzerland)*, *21*(4), 1373. https://doi.org/10.3390/s21041373.

Indrotristanto, N., Andarwulan, N., Dewanti-Hariyadi, R., & Fardiaz, D. (2023). Estimating The Rejection Risk of Indonesian Shrimp Exports from *Salmonella* spp. Contamination Using The Food Safety Objective Approach. *Food Control*, *153*, 109932. https://doi.org/10.1016/j.foodcont.2023.109932.

Kontominas, M. G., Badeka, A. V., Kosma, I. S., & Nathanailides, C. I. (2021). Recent Developments in Seafood Packaging Technologies. *Foods*, *10*(5), 940. https://doi.org/10.3390/foods10050940.

Madejska, A., Pawul-Gruba, M., & Osek, J. (2022). Histamine Content in Selected Production Stages of Fish Products. *Journal of Veterinary Research (Poland)*, *66*(4), 599–604. https://doi.org/10.2478/jvetres-2022-0063.

McCarthy, S., Bjornsdottir-Butler, K., & Benner, R. (2015). Storage Time and Temperature Effects on Histamine Production in Tuna Salad Preparations. *Journal of Food Protection*, *78*(7), 1343–1350. https://doi.org/10.4315/0362-028X.JFP-14-523.

Mercogliano, R., & Santonicola, S. (2019). Scombroid Fish Poisoning: Factors Influencing The Production of Histamine in Tuna Supply Chain. A review. *LWT*, *114*, 108374. https://doi.org/10.1016/j.lwt.2019.108374.

Mursit, A., Wahyono, A., & Setiawan, Y. (2022). Strategi Peningkatan Ekspor Produk Kelautan dan Perikanan ke Pasar Eropa. *Jurnal Manajemen*, *6*(2), 9–24. https://doi.org/10.54964/manajemen.v6i2.200.

Nugraha, I. M. A., Khairunnisa, A., & Cesrany, M. (2026). Strengthening Cold Chain Management in The Tuna Loin Industry in Bali: Efforts to Improve Product Quality and

Competitiveness. *Jurnal Penelitian Perikanan Indonesia*, *32*, 16–26. https://doi.org/10.15578/jppi.31.4.2025.177-185.

Nugroho, K. C., Mahjudin, Desembrianita, E., & Maulydya, F. D. (2022). Challenges and Obstacles of International Certification for Seafood Exporters in Indonesia. *International Journal of Economics, Business and Management Research*, *6*(8). https://doi.org/10.51505/ijebmr.2022.6812.

Prabhakar, P. K., Vatsa, S., Srivastav, P. P., & Pathak, S. S. (2020). A Comprehensive Review on Freshness of Fish and Assessment: Analytical Methods and Recent Innovations. *Food Research International*, *133*, 109157. https://doi.org/10.1016/j.foodres.2020.109157.

Purimahua, S., & Tupamahu, Y. (2022). Indonesian Tuna Economic Performance in The International Market. *Agrikan Jurnal Agribisnis Perikanan*, *15*(2), 689–700. https://doi.org/https://doi.org/10.52046/agrikan.v15i2.1297.

Resnia, R., Wicaksena, B., & Salim, Z. (2016). Kesesuaian SNI dengan Standar Internasional dan Standar Mitra Dagang pada Produk Ekspor Perikanan Tuna dan Cakalang. *Jurnal Standardisasi*, *17*(2), 87–98. https://doi.org/10.31153/js.v17i2.308.

Sarastani, D., Kusumanti, I., & Indriastuti, C. E. (2023). Uji Penerimaan Konsumen Terhadap Mutu Organoleptik Petis Ikan Situbondo dengan Metode Uji Kesukaan. *Bioscientist : Jurnal Ilmiah Biologi*, *11*(1), 32–45. https://doi.org/10.33394/bioscientist.v11i1.6984

Sayuti, M., Rafiani, E., & Salampessy, R. B. S. (2023). Quality Characteristics, Cold Chain System, Yield and Productivity of Frozen Tuna (*Thunnus albacares*) Steak Processing. *Pelagicus*, *4*(3), 121–134. https://doi.org/10.15578/plgc.v4i3.13077.

Suryono, M., Sumartini, S., & Aisy, R. (2023). Study of Quality Control on Tuna Loin Center Cut Frozen Production Using The Six Sigma Method in "X" Tuna Freezing Company. *Aurelia Journal*, *5*(1), 15–26. https://doi.org/10.15578/aj.v5i1.11531.

Suseno, H., & Suadi. (2021). Review of Standard Regulations on The Processing of Fishery Products in Indonesia. *IOP Conference Series: Earth and Environmental Science*, *919*(1), 012007. https://doi.org/10.1088/1755-1315/919/1/012007.

Tidd, A., Blanchard, J. L., Kell, L., & Watson, R. A. (2018). Predicting Global Tuna Vulnerabilities with Spatial, Economic, Biological and Climatic Considerations. *Scientific Reports*, *8*(1), 10572. https://doi.org/10.1038/s41598-018-28805-z.

Utari, S. P. (2023). Proses Pembekuan dan Pengujian Histamin Ikan Tuna (*Thunus* sp.) di PT. X, Banyuwangi. *Jurnal Perikanan dan Kelautan*, *13*(2), 107–117. https://doi.org/10.33512/jpk.v13i2.22360.

Wartini, S., Widyastuti, R., Mahargyo, D. P., Sasongko, D. B., Nugraha, J. P., & Laily, N. (2024). Export Procedure for Frozen Cooked Tuna (*Thunnus* sp.) Loin. *Jurnal Ilmiah Ekotrans & Erudisi*, *4*(2), 103–110. https://doi.org/10.69989/72wmds60.

Yadav, B., Fan, Y., Hrycauk, S., McAllister, T., Narvaez-Bravo, C., Brown, T., & Yang, X. (2025). Effects of Sanitation Practices on Microbial Dynamics in Meat Processing Environment. *Journal of Food Protection*, *88*(12), 100647. https://doi.org/10.1016/j.jfp.2025.100647.

Zalukhu, R. M. S., Sayuti, M., & Salampessy, R. B. S. (2023). Quality Testing of Frozen Cooked Tuna (*Thunnus albacares*) Loins. *Aurelia Journal*, *5*(1), 79–88. https://doi.org/10.15578/aj.v5i1.12041