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OPTIMIZATION OF COLD STORAGE MAINTENANCE FOR ENHANCING ENERGY EFFICIENCY IN FISHERY PROCESSING: A CASE STUDY OF XYZ COMPANY

Optimalisasi Pemeliharaan Gudang Pendingin untuk Meningkatkan Efisiensi Energi dalam Pengolahan Perikanan: Studi Kasus Perusahaan XYZ

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ABSTRACT

The fisheries industry requires an effective cold chain system to maintain product quality and food safety, with cold storage functioning as a critical component in maintaining temperature stability prior to distribution. However, operational problems such as temperature fluctuations, equipment failure, and power outages frequently threaten cold storage performance and may lead to product deterioration and economic losses. This study aims to analyze cold storage maintenance management at XYZ Company and evaluate its effectiveness in supporting cold chain optimization. The research employed a qualitative descriptive approach conducted from October to March 2025 at XYZ Company, Sidoarjo. Data were collected through semi-structured interviews with 10 purposively selected respondents, direct observation, and analysis of maintenance records, SOPs, and temperature data logs. The results indicate that the implementation of scheduled preventive maintenance, IoT-based real-time monitoring, and automated control systems effectively maintained temperature stability within standard limits. These measures reduced the risk of protein denaturation, recrystallization, and microbial growth in fishery products. Energy efficiency improved through inverter technology and better insulation, while backup power systems and emergency SOPs minimize operational risks. In conclusion, optimized cold storage maintenance significantly enhances energy efficiency, operational reliability, and product quality, while supporting HACCP and ISO 22000 compliance and strengthening cold chain integrity in the fisheries processing industry.

Keywords: Energy Efficiency, Equipment Reliability, Preventive Maintenance, Product Quality Assurance, Temperature Monitoring

ABSTRAK

Industri perikanan membutuhkan sistem rantai dingin yang efektif untuk menjaga kualitas produk dan keamanan pangan, dengan penyimpanan dingin berfungsi sebagai komponen penting dalam menjaga stabilitas suhu sebelum distribusi. Namun, masalah operasional seperti fluktuasi suhu, kerusakan peralatan, dan pemadaman listrik sering mengancam kinerja penyimpanan dingin dan dapat menyebabkan kerusakan produk dan kerugian ekonomi. Studi ini bertujuan untuk menganalisis manajemen pemeliharaan penyimpanan dingin di Perusahaan XYZ dan mengevaluasi efektivitasnya dalam mendukung optimasi rantai dingin. Penelitian ini menggunakan pendekatan deskriptif kualitatif yang dilakukan dari Oktober hingga Maret 2025 di Perusahaan XYZ, Sidoarjo. Data dikumpulkan melalui wawancara semi-terstruktur dengan 10 responden yang dipilih secara purposif, observasi langsung, dan analisis catatan pemeliharaan, SOP, dan log data suhu. Hasil menunjukkan bahwa implementasi pemeliharaan preventif terjadwal, pemantauan waktu nyata berbasis IoT, dan sistem kontrol otomatis secara efektif menjaga stabilitas suhu dalam batas standar. Langkah-langkah ini mengurangi risiko denaturasi protein, rekristalisasi, dan pertumbuhan mikroba pada produk perikanan. Efisiensi energi meningkat melalui teknologi inverter dan isolasi yang lebih baik, sementara sistem daya cadangan dan SOP darurat meminimalkan risiko operasional. Kesimpulannya, pemeliharaan penyimpanan dingin yang dioptimalkan secara signifikan meningkatkan efisiensi energi, keandalan operasional, dan kualitas produk, sekaligus mendukung kepatuhan HACCP dan ISO 22000 serta memperkuat integritas rantai dingin dalam industri pengolahan perikanan.

Kata Kunci: Efisiensi Energi, Keandalan Peralatan, Pemeliharaan Preventif, Jaminan Kualitas Produk, Pemantauan Suhu

INTRODUCTION

The fisheries and seafood industry plays a strategic role in the economy, both nationally and globally (Faturahman & Herwanto, 2023; Irhamsyah *et al*., 2017; Thorvaldsen *et al*., 2022). High-quality fishery products depend heavily on the effectiveness of the cold chain system, particularly in maintaining freshness and food safety. One key component of the cold chain is cold storage, which functions as a temperature-controlled storage facility to reduce the risk of damage and maintain product quality before distribution to the market (Pertiwi & Handayani, 2023; Qian *et al*., 2022). In Indonesia, optimal cold chain implementation remains a challenge, particularly in maintaining cold storage to ensure its proper and efficient functioning (Bianca, 2015; Pusporini & Dahdah, 2020).

In practice, various problems often arise related to the maintenance of these facilities. Operational disruptions such as unstable temperatures, cooling system disruptions, and the risk of power outages can directly impact the quality of stored products. If not properly managed, this can lead to significant economic losses, increased product wastage, and decreased market competitiveness (Gusdi & Sipahutar, 2021; Hakim & Erliza, 2019).

One strategy that can be implemented to address these issues is regular and planned cold storage maintenance management. This maintenance includes routine inspections, cooling system maintenance, cold storage cleaning, and maintenance of backup power systems (generators). This backup power system is crucial for ensuring cold storage operations continue during power outages, thus maintaining optimal storage temperatures (Setiawan *et al*., 2021; Siagian, 2017). With proper maintenance, the cold chain system will continue to operate efficiently and the quality of stored products will be maintained (Feng *et al*., 2017; Fernandes & McMeans, 2019; Wahab *et al*., 2023).

This research aims to analyze cold storage maintenance management strategies and demonstrate their effectiveness in supporting cold chain optimization. The study will also identify challenges faced in the maintenance process and develop recommendations that can be implemented to improve cold storage system efficiency. This research is expected to contribute to better cold storage management and serve as a reference for other fisheries industries in implementing effective and sustainable maintenance systems.

METHODS

Research Location and Time

This research was conducted at the cold storage facility of the fishery product processing company XYZ Company, located in Sidoarjo. The research activities were conducted during the period October 2024 to March 2025. This location was chosen because the company has an integrated cold chain system and routine cold storage maintenance activities, making it relevant to the research objectives of examining cold chain maintenance management and optimization strategies.

Research Design

This research used a qualitative method with a descriptive approach. The research design focused on analyzing the implementation of cold storage maintenance management and formulating cold chain optimization strategies based on actual conditions in the field. This study did not use statistical hypotheses, but rather research questions oriented towards the implementation of cold storage maintenance management, operational constraints, and optimization strategies that can be implemented to improve cold chain effectiveness in fishery product processing companies.

Research Tools and Materials

The tools used in this research included a semi-structured interview guide, observation sheets, documentation tools such as cameras and voice recorders, and temperature data recording devices available at the company, such as data loggers or temperature monitoring systems. The research materials consisted of internal company documents, including maintenance reports, equipment failure records, standard operating procedures (SOPs), and cold storage temperature data records, which served as the basis for analyzing the performance of the cold chain system.

Research Procedure

The research procedure was implemented through several structured stages. The first stage was research preparation, which included literature review, development of interview instruments, and coordination with the company. The next stage was primary data collection through in-depth interviews with operational managers, maintenance personnel, and related staff using purposive sampling techniques, as well as direct observation of facility conditions, refrigeration systems, and ongoing maintenance practices. Secondary data was then collected from maintenance documents, operational reports, and company archives related to cold storage management. After data collection, verification was conducted through triangulation of sources and methods to ensure the validity of the information. The final stage was the formulation of an optimization strategy based on field findings combined with relevant theoretical studies.

Sampling Technique

Respondents in this study were selected using purposive sampling, which involves selecting informants based on specific considerations that align with the research needs. Respondent criteria included direct involvement in cold storage operations, an understanding of maintenance procedures, and a minimum of 2 years of work experience in a related field. The number of respondents involved was 10, and was expected to provide comprehensive information regarding maintenance management practices in the company.

Data Analysis

The data obtained was analyzed using thematic analysis techniques, which included data reduction, coding, categorization, and the extraction of key themes. To maintain data validity, source triangulation was conducted by comparing the results of interviews, observations, and written documents, as well as method triangulation and discussions with key informants through member checking. The results of this analysis were used as a basis for evaluating the effectiveness of cold storage maintenance management and formulating applicable cold chain optimization strategies to improve operational efficiency and company sustainability.

RESULTS

Cold Chain Implementation in the Surimi Manufacturing Process

The application of cold chain in fisheries processing, for example surimi, is very important to ensure product quality. The surimi production process involves several critical steps that must be carried out under controlled temperature conditions, no higher than 10°C. The entire process is carried out under strict temperature controls to ensure the surimi maintains its quality and is safe for consumption. The steps are clearly outlined in Table 1.

Table 1. Application of Cold Chain in the Surimi Manufacturing Process

Process	Description	Temperature (°C)
Raw Material Receiving	The fish used as raw material is received and immediately stored at low temperature to prevent deterioration	7
Fish Washing	Conducted to remove dirt and bacteria that may affect product quality	5–10
Rotary Screening I, II, and III	Gradual screening process to separate unwanted parts and impurities	10
Bleaching	Whitening process to improve the color quality of surimi	10
Refining and Screw Press	Purification and dewatering process to obtain optimal surimi texture	5–10
Weighing II and Mixing	Surimi is re-weighed and mixed with additives according to formulation	22
Filling and Weighing III	The product is filled into packaging and re-weighed to ensure uniform weight	22
Freezing	Surimi is frozen to maintain freshness and extend shelf life	–40
Metal Detecting and Packing	Inspection for metal contamination and final packaging before storage in cold storage	–25
Cold Storage	Maintaining product quality, extending shelf life, and preventing deterioration during storage	–18

Figure 1. Post-Processing Flow of Surimi Prior to Cold Storage

The surimi product that has gone through the mixing stage is packed into packaging according to company standards, then reweighed to ensure uniform weight in each package so that it meets quality specifications and product label requirements. After that, the product is sent to a freezing unit with an ultra-low temperature to maintain freshness and functional characteristics of the protein, as well as inhibiting the activity of microorganisms and biochemical reactions that can cause quality degradation so that the product's shelf life can be optimally extended. Before being stored in cold storage, a metal contamination check is carried out using a metal detector as a quality control and food safety measure, then the product is finally packaged and transferred to the frozen storage room to maintain quality stability until the distribution stage as part of the implementation of a controlled and sustainable cold chain system. This activity can be clearly seen in Figure 1.

The Role of Cold Storage in Cold Chain Implementation

Cold storage is a storage system specifically designed to store food and beverage products at low temperatures to extend their shelf life. In fishery processing, cold storage plays a critical role in maintaining product quality and safety by inhibiting microbial growth and slowing biochemical degradation processes. In this study, cold storage is used to maintain the quality of surimi and extend its shelf life by ensuring stable frozen conditions throughout the storage period.

At XYZ Company, three cold storage units are utilized for surimi storage: two units located inside the factory and one unit located outside the factory. The internal cold storage units have a combined capacity of up to 70 tons, while the external cold storage unit has a storage capacity of up to 300 tons. The operating temperature of all cold storage units is consistently maintained within the range of –18°C to –20°C, which complies with standard requirements for frozen fishery products and supports the stability of product quality during storage.

Cold storage systems represent one of the largest energy-consuming components in fishery processing facilities. Therefore, effective cold storage maintenance is closely associated with overall energy efficiency. At XYZ Company, cold storage maintenance activities are conducted regularly to ensure optimal system performance and prevent equipment failure that could lead to excessive energy consumption. These activities include routine inspections of refrigeration components, maintenance of cooling systems, cleaning of cold storage rooms to maintain proper air circulation, and monitoring of temperature stability to avoid unnecessary compressor workload caused by temperature fluctuations.

In addition, the maintenance of evaporators and condensers plays a crucial role in heat transfer efficiency. Fouling or ice buildup on these components can reduce cooling efficiency and increase electrical energy demand. Regular defrosting and cleaning procedures implemented at XYZ Company contribute to maintaining efficient heat exchange and stable operating conditions. As a result, the refrigeration system can operate more efficiently while maintaining the required storage temperature.

To ensure operational reliability, a backup power system in the form of a generator is also maintained as part of the cold storage maintenance program. This system serves as an alternative power source in the event of power outages from the main electricity supplier. The availability of a backup power system helps prevent sudden temperature increases during power interruptions, thereby reducing the need for additional energy during system recovery and minimizing the risk of product quality deterioration.

Overall, the observed cold storage maintenance practices at XYZ Company provide a baseline for evaluating optimization strategies aimed at enhancing energy efficiency and operational reliability. These findings serve as an important reference for further analysis of maintenance optimization and its impact on energy consumption in cold storage operations.

Table 2. Cold Storage Data

Cold Storage	Description
Product	Surimi
Cold storage temperature	–18°C to –20°C
Cold storage color	White
Cold storage dimensions	12 × 6 × 4 m and 10 × 3 × 4 m
Capacity	300 tons and 70 tons
Electrical power	1,230 – 2,000 watts

DISCUSSION

Cold Storage Maintenance Management Optimization Strategy

A cold storage maintenance management optimization strategy is crucial for maintaining product quality, especially in food processing industries like surimi. One key step is implementing scheduled preventative maintenance, which involves routine inspections of equipment such as refrigeration machines, air circulation systems, and temperature sensors. This aims to detect potential problems before they become major damage that could impact product temperature and quality. Furthermore, implementing real-time temperature monitoring technology using IoT systems and data loggers is helpful in monitoring temperature and humidity throughout the cold storage area, providing automatic notification of any undesired changes. The use of automated control systems can also optimize temperature and humidity settings efficiently, reducing reliance on manual intervention (Alkahtani *et al*., 2024; Gillespie *et al*., 2023; Mohammed *et al*., 2022; Protopappas *et al*., 2025).

Increasing energy efficiency is also a key focus, given that cold storage is an energy-intensive facility. By using inverter technology and ensuring proper insulation, energy savings can be achieved without compromising storage performance. Maintaining a backup power system and safety procedures for emergencies, such as power outages, is also crucial for maintaining the smooth operation of cold storage. In addition, regular training for the maintenance team and cold storage users is necessary to ensure that all parties understand maintenance procedures and can quickly identify technical issues. Regular performance data analysis and system audits are also essential to identify areas for improvement. Overall, this strategy ensures that cold storage operates efficiently, maintains the quality of stored products, and minimizes the risk of losses due to product damage (Sageer *et al*., 2025).

Optimizing cold storage maintenance management is crucial to ensure the smooth operation of the entire cold chain and the maintenance of product quality (such as surimi). A more detailed strategy for optimizing cold storage maintenance management is presented in Table 3.

Table 3. Cold Storage Maintenance Management Optimization Strategies

Strategy	Description
Scheduled Preventive Maintenance	Inspection and maintenance of cold storage equipment must be carried out regularly to ensure optimal and safe operation. These inspections include refrigeration units, air circulation systems, and temperature sensors. Key activities involve checking for refrigerant leakage, cleaning evaporators and condensers, and inspecting temperature control systems to prevent failures that may disrupt storage processes. In addition, periodic calibration of temperature and humidity sensors is essential to ensure accurate data readings. Battery testing and replacement for automatic temperature monitoring devices must also be performed to avoid measurement errors that could affect product quality. Furthermore, temperature and humidity conditions inside the cold storage must always be maintained within the required range. Temperature testing should be conducted at multiple points, particularly in critical product storage areas, to ensure temperature uniformity and prevent undetected temperature deviations that may lead to product deterioration.
Improvement of Monitoring Technology and Automation	The implementation of real-time temperature monitoring systems is crucial for maintaining temperature stability in cold storage. This system can utilize Internet of Things (IoT) technology capable of monitoring temperature at multiple points simultaneously and providing automatic alerts when temperatures exceed predefined limits. With direct notifications to the maintenance team, issues related to temperature or humidity can be addressed immediately before affecting product quality. In addition, the installation of data loggers is required to continuously record temperature and humidity data. The collected data can be used to analyze system performance and identify areas requiring improvement. Furthermore, the use of an Automatic Control System (ACS) can optimize temperature and humidity management through automatic adjustments based on actual needs. This approach not only reduces dependence on manual intervention but also minimizes the risk of human error. Through this technological integration, cold storage management becomes more efficient, safe, and reliable.
Scheduling of Preventive and Corrective Maintenance	Systematic and scheduled maintenance of cold storage equipment is essential to prevent unexpected failures and ensure optimal operation. Routine maintenance schedules must be established for major equipment such as refrigeration units, thermal insulation, and air circulation systems. For example, air filter maintenance and evaporator cleaning should be performed every three months to maintain equipment performance and prevent efficiency decline. In addition to routine maintenance, corrective maintenance must also be well prepared. In the event of unexpected failures, such as compressor malfunction or drastic temperature drops, the company must have clear maintenance procedures. The maintenance team should be adequately trained to handle such problems quickly and effectively. To support rapid repair processes, commonly required spare parts such as filters, sensors, and compressors must always be available. Thus, repairs can be carried out immediately without waiting for spare part delivery, minimizing downtime and maintaining product quality.

Strategy	Description
Human Resource Training and Competence	Training and skill development for maintenance teams and cold storage operational staff are vital to ensure efficient and safe operations. The maintenance team must receive regular training on proper maintenance procedures, troubleshooting techniques, and the use of the latest technologies applied in cold storage. This training enables them to handle technical problems quickly and effectively while maximizing equipment performance. In addition, education for users, particularly operators directly involved in cold storage operations, is also necessary. They must understand how to handle temperature-related issues and be able to perform basic inspections routinely to prevent operational disruptions. Furthermore, knowledge of industry standards such as Hazard Analysis and Critical Control Points (HACCP) and ISO 22000 is essential for the maintenance team. Understanding these standards ensures that all cold storage processes comply with food safety and quality requirements. With appropriate training and adequate understanding of industry standards, cold storage operations can run optimally, safely, and in accordance with applicable regulations.
Energy Use Optimization	Energy saving is a critical aspect of cold storage operation, considering that this facility is one of the most energy-intensive in the industry. Several strategic measures can be implemented to optimize energy consumption. First, the use of inverter technology in refrigeration systems is highly effective in reducing electricity consumption, as it can adjust compressor speed according to cooling demand. Second, the application of renewable energy, such as solar panels, can be a sustainable solution to reduce dependence on conventional electricity. In addition, proper insulation must be ensured by using high-quality thermal insulation to maintain stable indoor temperatures without excessive energy use. Lastly, door management also plays an important role in energy efficiency. By limiting door opening frequency and ensuring doors are tightly closed, cold air can be retained inside, thereby minimizing energy consumption required to maintain temperature stability. Through these measures, cold storage operations can become more energy-efficient, cost-effective, and environmentally friendly.
Quality Management and Control	Periodic product quality testing is essential to ensure that cold storage functions optimally in maintaining product quality, particularly in preserving texture, taste, and freshness. This testing helps identify potential quality degradation caused by temperature or humidity fluctuations. In addition, quality audits and inspections must be conducted regularly. These audits include temperature measurements throughout the cold storage area to ensure uniform temperature distribution in accordance with standards. Visual inspection of stored products is also important to detect signs of damage or quality decline. These measures aim to ensure that no areas experience higher temperature or humidity levels that could lead to product deterioration. Through consistent testing, auditing, and inspection, product quality can be properly maintained throughout the cold storage period.

The Impact of Optimizing Cold Storage Maintenance on the Quality and Safety of Fishery Products

Temperature stability is the most crucial factor in the storage of fishery products, particularly surimi and frozen fish. Fishery products are highly perishable due to their high air, protein, and unsaturated fat content, which are susceptible to chemical and microbiological degradation. Temperature fluctuations during cold storage can accelerate protein denaturation, fat oxidation, and the growth of spoilage-causing microorganisms. Therefore, maintaining the acoustics of the refrigeration system through maintenance management is a key prerequisite for maintaining product quality (Nakazawa & Okazaki, 2020).

In surimi products, temperature stability below -18°C plays a crucial role in maintaining gel-forming ability, a key quality parameter. Increased temperature, even temporarily, can trigger protein aggregation, which reduces gel strength, elasticity, and air-holding capacity. This impact directly affects the textural quality of final products such as fish balls or other surimi-based products. Similarly, in whole frozen fish, temperature can cause recrystallization, which produces large ice crystals and damages the muscle tissue structure. After thawing, this condition can lead to increased drip loss, discoloration, and decreased flavor, thus reducing the product's commercial value (MacDonald *et al*., 2013; Tan *et al*., 2021; Yin *et al*., 2025).

Refrigeration system failures, such as compressor failure, refrigerant leaks, or evaporator performance degradation, can cause rapid and uncontrolled increases in storage temperatures (Sun *et al*., 2021; Zhang *et al*., 2024). In a large-capacity fishery processing industry like Company XYZ, this situation has the potential to cause significant product damage. Optimizing maintenance through the implementation of preventive maintenance and IoT-based monitoring plays a critical role in mitigating this risk. Early detection of signs of performance degradation, such as increased compressor current, refrigerant pressure anomalies, or uneven temperature distribution, allows corrective action to be taken before a total failure occurs, thus minimizing potential losses from temperature misuse.

In addition to affecting physical quality, temperature control failures also have microbiological implications. At temperatures above critical limits, spoilage bacteria such as *Pseudomonas* sp. and *Shewanella putrefaciens*, as well as histamine-producing bacteria, can grow more rapidly. These conditions not only reduce sensory quality but also increase food safety risks. Therefore, cold storage maintenance management serves as a crucial layer of protection to prevent contamination and product deterioration during storage.

Cold storage maintenance management is directly linked to the implementation of food safety systems, particularly within the HACCP and ISO 22000 frameworks. Storage temperature is a Critical Control Point (CCP) in the fishery product cold chain, and failure to maintain the required temperature can lead to uncontrolled biological and chemical hazards. Planned maintenance, including temperature sensor calibration, evaporator cleaning, room insulation checks, and electrical system testing, ensures that critical parameters are consistently controlled. Historical data from data loggers also provides objective evidence that products are stored under conditions that meet cold chain integrity requirements.

The implementation of a maintenance strategy at XYZ Company has significantly contributed to maintaining storage temperatures within the standard range, reducing temperature deviations, reducing customer complaints, and improving compliance with food safety audits. Therefore, optimizing cold storage maintenance not only impacts energy efficiency but also serves as a key foundation for sustainably maintaining the sensory quality, nutritional value, and safety of fishery products.

Operational Risk Management and Cold Storage Reliability

Operational reliability of cold storage is a key element in maintaining the continuity of the fishery product cold chain. Refrigeration systems operate continuously under high loads, making them vulnerable to various technical and non-technical disruptions. Key operational risks that frequently occur include compressor failure, refrigerant leaks, decreased evaporator and condenser performance, and power outages. If these disruptions are not promptly addressed, storage room temperatures can rise beyond critical limits and lead to rapid product deterioration (Du *et al*., 2016; Zhang *et al*., 2024). Therefore, risk identification and establishing mitigation measures are essential for optimizing cold storage maintenance at XYZ Company.

As the most vital component in a refrigeration system, the compressor is highly susceptible to mechanical wear, voltage imbalances, and inadequate lubrication. Compressor failure will stop refrigerant circulation, drastically reducing cooling capacity. Conversely, refrigerant leaks and dirt buildup in the condenser can increase the system's workload, increase energy consumption, and accelerate component degradation. Power outages also pose a significant threat because, without backup power, temperature increases can occur quickly, especially in cold storage with high product densities. This situation has the potential to lead to temperature abuse, leading to quality degradation and economic losses (Karacan *et al*., 2023; Morozyuk *et al*., 2023).

From a food safety perspective, storage temperature control is a key Critical Control Point (CCP) in the fishery product cold chain. This critical point relates not only to room temperature but also to uniform temperature distribution, sensor accuracy, and response speed when deviations occur. Parameters that must be controlled include the maximum storage temperature limit, the tolerance duration for temperature increases, the reliability of sensor calibration, the frequency of door opening and closing, and the system's ability to handle peak loads. If any of these parameters are not met, the CCP status is considered out of control and can threaten product safety. Therefore, real-time monitoring using data loggers and IoT systems is a crucial tool to ensure any deviations are quickly detected and documented as a basis for corrective action.

To minimize the impact of system failures, the existence of backup systems and procedural readiness are strategic components. The implementation of automatic generators, backup compressors, and integrated temperature alarm systems allows operations to continue in the event of power outages or main unit failures. In addition, emergency Standard Operating Procedures (SOPs) regulate communication flows, personnel assignments, product handling procedures, and mechanisms for transferring to alternative facilities. Regular training for operators and maintenance teams ensures a rapid and coordinated response to critical conditions, minimizing exposure to unsafe temperatures.

With this approach, cold storage operational risk management at XYZ Company focuses not only on corrective actions after damage occurs but also emphasizes prevention and preparedness. The integration of risk identification, CCP control, backup system availability, and the implementation of emergency SOPs has been proven to improve cooling system reliability, maintain storage temperature stability, and protect the quality and safety of fishery products during storage.

Compliance of Cold Storage Management with Food Safety Standards and Regulations

Cold storage management in the fisheries processing industry requires not only technical operational compliance but also compliance with applicable food safety standards and regulations. Management systems such as Hazard Analysis and Critical Control Point (HACCP) and ISO 22000 prioritize temperature control as a key element in maintaining cold chain integrity. Within the HACCP framework, frozen storage temperature is designated as a Critical Control Point (CCP) because it directly influences the growth of pathogenic microorganisms, enzymatic activity, and the stability of the sensory quality of fishery products.

Storage standards for frozen fishery products generally require a maximum temperature of -18°C with very limited tolerance for fluctuations. Failure to meet these limits can accelerate deterioration processes such as fat oxidation, protein denaturation, and increase the number of spoilage microorganisms. Therefore, regulations require a documented temperature monitoring system, regular sensor calibration, and a corrective action mechanism for deviations. The implementation at XYZ Company demonstrated that the use of data loggers and an IoT-based monitoring system can provide continuous temperature recording, facilitating verification of compliance with HACCP and ISO 22000 requirements.

ISO 22000 emphasizes the importance of a risk-based approach and traceability at all stages of the food chain. In the context of cold storage, this translates into documented operational procedures, validation of refrigeration equipment performance, and the competency of involved personnel. Planned maintenance, such as evaporator cleaning, refrigerant leak checks, and room temperature uniformity verification, are prerequisites for supporting the effectiveness of CCP programs. Without adequate maintenance, temperature control cannot be guaranteed, even with well-established HACCP procedures.

Good cold chain industry practices also emphasize the importance of appropriate facility design, door opening and closing management, product layout, and adequate system capacity for peak loads. Excessive product stacking or obstructed air circulation can lead to temperature irregularities and create hot spots within the storage space. Therefore, in addition to technological aspects, operational discipline is a determining factor in the success of standard implementation. At XYZ Company, the implementation of product arrangement procedures, door opening time restrictions, and routine temperature distribution inspections have been proven to support the achievement of good cold chain practices.

Compliance with standards and regulations also has strategic implications for the company's competitiveness. Compliance with HACCP and ISO 22000 increases customer trust, facilitates access to export markets, and reduces the risk of product rejection due to quality nonconformities. Regular internal and external audits encourage continuous improvement in cold storage management, including increasing energy efficiency and system reliability.

Therefore, cold storage management at XYZ Company has integrated HACCP requirements, ISO 22000, fishery product storage temperature standards, and good cold chain practices into its operational system. This integration ensures that the storage process is not only energy efficient but also meets the principles of food safety, traceability, and sustainable fishery product quality protection.

CONCLUSION

Optimizing cold storage maintenance at XYZ Company has proven effective in improving energy efficiency, operational reliability, and the quality and safety of fishery products. The implementation of scheduled preventive maintenance, real-time IoT-based monitoring, and an automated control system successfully maintained temperature stability at required standards, thus preventing product deterioration such as protein denaturation, recrystallization, and microbial growth.

Energy efficiency was improved through the use of inverter technology, improved insulation, and proper operational practices, resulting in reduced electricity consumption without compromising cooling performance. Strengthened operational risk management, including backup power systems, early failure detection, and emergency SOPs, significantly minimized the risk of temperature misuse and economic losses.

Furthermore, the maintenance strategy supports compliance with HACCP and ISO 22000 requirements, ensures cold chain integrity, and enhances product traceability. Overall, optimizing cold storage maintenance serves as a strategic approach that integrates energy efficiency, food safety assurance, and sustainable fishery product quality protection.

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