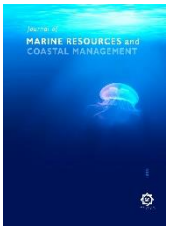
JOURNAL OF MARINE RESOURCES AND COASTAL MANAGEMENT
INDONESIAN JOURNAL OF MARINE LIFE AND UTILIZATION

e-ISSN: 2722-0966
Vol. 4 Issue 2



Performance of refrigeration unit using monitoring of temperature, humidity and power consumption of freezer machine at Jaya Bahari cold storage

Radityo Nugrowibowo*, Asri Sawiji, and Muhammad Yunan Fahmi
Marine Science Department, Faculty of Science and Technology, UIN Sunan Ampel Surabaya, Indonesia
*E-mail: nugrowibowo1823@gmail.com

ABSTRACT

Fishery products generally spoil more quickly than other animal meat products. After being caught, fish will experience changes in quality, the level of these changes will determine the shelf life of the fish. Handling fresh fish is the most important aspect of a fisheries business. Cold storage is a way of storing fish at a certain temperature which allows fresh fish to be stored for long periods, even months, to prevent bacterial growth. This research aims to evaluate the implementation of the Standard Operating Procedure (SOP) for storing fish in cold storage using the First In First Out (FIFO) system and to evaluate the quality of the cooling system using temperature and humidity monitoring at Jaya Bahari cold storage. The method used in this research is measurement, interviews and literature study. The process stages in receiving fish products start from unloading fish, thawing frozen fish, weighing and testing samples, sorting and calculating the percentage of rejects, as well as temporary storage by looking at various obstacles during the process of receiving raw materials. The performance of the data logger and big data each showed results that were not much different with the respective tool accuracy values of 99.26% for temperature measurements and 99.83% for humidity measurements. Defrosting ice for 2 hours can save power by 4.37%.

Keywords: cold storage, data logger, fish, freezer, humidity, power consumption, temperature

INTRODUCTION

Distribution of fisheries catches is very important because fisheries catches are foodstuffs that is easily damaged and then rots [1], so distribution are needed so that sales of the catch can reach consumers for consumption. On average, products stored in cold storage come from outside the island. Apart from that, the distribution of fishery products is very important because they can be sold widely to where consumers are, making it easier for consumers to get the products they need [2-5].

With the increasing demand for domestic and foreign fish products, more attention must be paid to the quality of fish so that it meets quality standards. The quality and physical condition of a product is very important in the distribution process to meet consumer satisfaction [4]. Good handling and processing can be done through cooling and freezing. In addition, shelf life will also be extended by refrigeration and freezing. Freezing can also mean storing food frozen for enzymatic and chemical reactions [5-6].

Fish is one of the important elements of fisheries which play a role in the processing of fishery products. In relation to the marine sector, fish is one of the most processed marine products in Indonesia, therefore optimizing marine fish food must be through correct processing [7-8]. Fishery products generally spoil more quickly than other products such as meat. After being caught, fish will experience changes in quality, the level of these changes greatly determines the shelf life of the fish. Handling fresh fish is the most important aspect of a fisheries business. If appropriate handling methods are used, the quality of the fish will increase and the selling value to consumers will be higher [9].

Fish protein is easily damaged if exposed to bacteria. One way to deal with preserved fish so that its freshness is maintained optimally is to reduce the fish's body temperature (cooling). Cold storage is a way of storing fish at a certain temperature which allows fresh fish to be stored for a long period of time, even months, to prevent the growth of bacteria in the fish. The use of mechanical cooling in the fishing industry, the process of reducing product temperature is considered the most efficient compared to other methods so that cooling is needed to maintain fish quality [8, 10]. Handling fresh fish requires correct procedures in accordance with predetermined standards.

Jaya Bahari is a company that provides freezer and cold storage rental services to maintain the quality of fresh fish and other seafood products. This company's facilities can store up to 1,000 tons of product in a strategic location and has a large area to facilitate the loading and unloading process which can accommodate 8 containers and there are technicians and security who maintain the condition of the product 24 hours in the storage warehouse.

The fish supply chain in Jaya Bahari cold storage comes from suppliers, imports from abroad, outside the island and outside the city. Jaya Bahari cold storage in the process of handling fresh fish uses a cooling machine

whose temperature has been adjusted to the standards of the Fish Quarantine, Quality Control and Safety of Fishery Products (BKIPM). ranges from -18oC to -20oC, but still cannot reach the applicable temperature standards even though using a data logger.

The process of decreasing fish quality will continue if it is not stopped. This requires good handling and processing through cooling and freezing, so that it will extend the shelf life by freezing. Freezing can also be interpreted as storing food in a frozen state, so that enzymatic reactions, chemical reactions that cause damage and spoilage can be inhibited.

Therefore, it is necessary to review the procedures for handling fish in the Jaya Bahari cold storage so that they comply with applicable standards. This research aims to evaluate the implementation of the Standard Operating Procedure (SOP) for storing fish in cold storage using the First In First Out (FIFO) system. This research also aims to evaluate the quality of the cooling system using temperature and humidity monitoring.

METHODS

Research on the quality of the cooling system using temperature and humidity monitoring was carried out at the Jaya Bahari cold storage located in the Asemrowo area, Greges sub-district, Surabaya. This research uses observation and interview methods.

The observation method is a method of making a direct observation and recording information that can support the preparation of research reports. Observations made include the process of offloading fish, sorting fish, storing fish and the tools used. The offloading process is the process of lowering fish from container trucks into cold storage. Fish sorting is the process of sorting fish based on fish type, owner's name and fish size. Fish storage is the process of stacking fish shelves based on entry time.

The interview method is a method of asking structured and unstructured questions and can also be free questions with the aim of obtaining broad information. This research was conducted using an interview method without a questionnaire with questions that had been prepared previously. This interview was conducted with cold storage Jaya Bahari employees who take care of the fish storage section.

Data Collection

Data collection using a big data monitoring system with variables of temperature, humidity and cold storage power consumption. Data collection is carried out for 1 month. Data collection of temperature, humidity and electrical power consumption is done in near real time. Setting on the microcontroller is done by doing a loop every 100,000 milliseconds or 100 seconds or 1 minute 30 seconds. This means that data collection is carried out per 1.5 minutes for temperature, humidity and power consumption.

Data Analysis

Data analysis that will be used in comparison data using a temperature sensor module with a data logger located on a cooling machine. Analysis in finding the deviation between the data obtained with the sensor module and the data that has been obtained in the data logger. To determine the accuracy of the data from the sensor module with data from the data logger which uses the standard deviation as shown in Equation (1). Errors and the percentage of accuracy on instrumentation tools then calculated using Equation (2) and (3), respectively.

$$S = \frac{\sqrt{\sum(x_i-\mu)^2}}{N} \quad (1)$$

where S is deviation value, N is total data, x_i is initial data, and μ is data average.

$$\text{Tools error (\%)} = \left|\frac{\sum_{i=1}^{n} (Xi-Yi)}{\sum_{i=1}^{n} Yi}\right| \times 100\% \quad (2)$$

where X is converted instrumentation data, and Y is converted data logger tool data.

$$\text{Tools accuracy (\%)} = 100\% - \text{Tools error (\%)} \quad (3)$$

RESULTS AND DISCUSSIONS

SOP of Fish Storage

SOP are documents that are written precisely and concisely to describe the procedures used to carry out organizational policies and activities, as set out in the guidelines. Procedures are written instructions that serve as guidelines in completing a routine or repetitive task effectively and efficiently, in order to avoid variations or deviations that can affect the overall performance of the company [11]. The application of the SOP in cold storage for fish storage is to avoid mistakes, one of which is in the process of receiving fish raw materials. The existing SOP makes standard provisions for officers in doing work and every activity can be controlled properly.

In this study, the SOP FIFO system of fish pallet arrangement is carried out according to the production order and production code based on SNI 8222: 2016. Fish handling is carried out with a FIFO system, i.e. fish that arrive early will be processed first. The FIFO method is a principle where the first product to arrive and be stored must be the first distribution. The application of the FIFO system carried out in the cold storage room is intended to prevent damage to products whose production has been long [12]. Fish products that have been offloaded are first recorded by staff on the tally sheet. The next process is checking by the owner of the fish first in the anterum for 30 minutes.

The fish production process is carried out quickly and carefully while maintaining the cold chain. Frozen products must be stored properly, cartons of frozen fish products must be neatly arranged according to the processing time. Transportation to store and remove products must be done quickly and safely and not cause temperature fluctuations in cold storage.

There are several processes when the fish process enters the cold storage (Table-1 and 2) including:

1. *Frozen fish raw material*. The fish raw materials received are raw materials in frozen form brought by containers from suppliers, fisher from Madura, Bali, Central Java, East Java. Frozen fish raw materials are sent using container trucks, frozen fish in containers are wrapped in cardboard boxes. The process of receiving frozen fish raw materials before being put

into cold storage is carried out recording the receiving and checking the frozen fish raw materials

2. *Offloading*. The process of offloading fish from the container truck takes approximately two to four hours depending on the size of the container truck carrying the fish. The container that brings fish to cold storage Jaya Bahari has two types of sizes, i.e. the 20 fit size which contains 11 tons of fish, while the 40 fit size container contains 25 tons of fish. The size of fish at cold storage Jaya Bahari ranges from 50-100 for pelagic fish, for demersal fish it ranges up to 1000. In the process of arranging the fish on the pallet, the placement is adjusted to the size, grade and name of the owner to facilitate the retrieval process when the goods will come out.
3. *Sorting*. The sorting process is very important because at this stage the sorting of fish products is carried out in order to obtain quality fish. Fresh fish has the physical characteristics i.e. not physically deformed, has fresh eyes, shiny scales and does not smell bad. The sorting process has several stages, i.e. fish size, fish grade, fish size, fish condition and is carried out in anterum cold storage for 30 minutes
4. *Storage in cold storage*. The fish in the box are neatly arranged on pallets that have been adjusted based on the type, size, grade and name of the owner. The storage room in cold storage has a freezing temperature between -18°C to -25°C, under these conditions the product quality will be maintained . Fish storage in cold storage must use pallets as a reason so that the process of moving from the container into cold storage becomes easier.
5. *Packaging*. During the distribution process, packaging is very important and useful so that fish products are well protected. Labeling the master carton based on the type of fish, weight of fish, product code and quantity of fish is to provide valid information to consumers.
6. *Stuffing*. Fish is put into cold storage with a temperature of 25°C for an uncertain period of time, after which it is neatly arranged so that it is free from damage. When the storage room is full and there is a request from consumers, the delivery process will be carried out.

SOP for Dispensing Fish in Cold Storage

Fish that has been stored in cold storage will usually be released if there are consumers who want to buy fish products. The next stage is the process of the product being produced, verified and packaged and coordinated for delivery to consumers.

The process of releasing fish products when packaging must use a master carton as packaging. Delivery of products to consumers using means of transportation, such as ships, trailers, trucks, pick-ups, and refrigerator containers specifically for fish exports. Delivery time for export products can reach one month.

SOP to Achieve Temperature Stability

It is known that when the temperature curve looks sloping or the temperature can no longer drop, there will be a process of forming ice flowers on the evaporator. When the temperature can no longer drop, the staff will check the state of the cold storage where there are ice flowers that cover the evaporator and make defrost adjustments where when the defrost is turned on, the freezer machine will automatically turn off and the heater turns on to carry out the defrosting process.

The existence of a big data-based monitoring system has benefits in cold storage, i.e. temperature and humidity are easily monitored properly and action can be taken if there is an increase in temperature and humidity by turning off or turning on the freezer machine, in this big data-based monitoring system there is also monitoring the power consumption of the freezer machine with this monitoring the manager can determine the duration of defrost time.

Cold storage applies a storage temperature of -18 °C to -25°C in cold storage, with the application of low temperatures according to applicable standards, the shelf life of fish also has a long time. The procedure applied at cold storage is carried out with a pre order system with an example if the product with a volume of 20 tons has been processed, the shipping process will be carried out. The storage time depends on the validity but for the storage time in cold storage of fish during freezing, the average time is up to 2 years.

Monitoring System Accuracy Level

The performance of cold storage as an object of observation is only monitored by the average temperature, the level of air humidity is not measured. This is only to fulfill the provisions of technical audits from independent agencies. So that the consistency of cooling quality according to cooling standards is less attention. The previous monitoring system used a data logger device, where the temperature sensor module was installed in the cold storage room, then after a few days the module was taken, then the raw data was taken and entered into an application that could display a graphical visual form as well as the calculation of the average temperature. The system to be implemented in this study is an Internet of Things (IoT)-platform monitoring system with the concept of big data.

Problems in monitoring temperature and humidity in cold storage must be controlled properly so that the quality of fish can be maintained. The existence of this problem requires an IoT-based surveillance system, so the cold storage room can always be monitored properly such as a room that is always tightly closed and workers there know about changes in temperature and humidity that increase in cold storage [13].

Big Data-Based Monitoring System

Temperature, humidity, and power consumption of freezer and heater machines are taken per minute (near real time) to obtain large data. The existence of large and detailed data can easily be analyzed in more detail. The raw data that has been recorded in cloud data storage is then processed into a graphical display curve (Figure-1) so that it is easy to see the events or trends of the process properly. Figure-1 shows an example of a display of a Big Data-Based Monitoring System along with examples of raw data taken from a small part of such a large amount of data, as an illustration of the comparison of the number of data items between the data logger system (temperature and humidity) and this monitoring system (temperature, humidity, and power consumption).

Table-1. SOP of fish receiving process

Activities	Activities			Quality Standard
	Staff	**Daily Worker**	**Fish Owner**	**Requirements**
Fish owners apply for fish storage in cold storage			Start	The owner notifies the cold storage
Daily workers prepare trolleys and pallets for loading into cold storage.				1. Trolley 2. Pallet (fish rack)
Staff record incoming fish by type, quantity and owner's name on the tally sheet.				1. Owner's name 2. Type of fish 3. Quantity 4. Date of Production
The fish owner checks the quality of the fish before putting it into the cold storage for ±30 minutes.				
Staff sorting fish that are not of good quality				
Officers marginalize fish whose quality is not good / not according to standards				Container for separating
Daily workers arrange fish on pallets based on fish type, grade and size.				1. Pallet (fish rack) 2. Fish data
Daily workers arrange fish racks according to production date in the cold storage.	Finish			

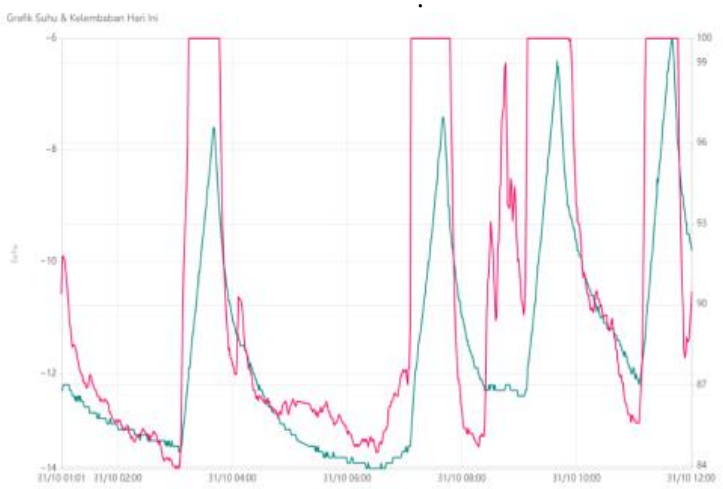


Figure-1. Big data monitoring system chart

Table-2. SOP of fish expenditure

Activities	Executive			Quality Standard
	Staff	**Daily Worker**	**Fish Owner**	**Requirements**
Consumers who want to buy fish products contact the staff of Cold storage	Start			The owner notifies the cold storage
Staff get orders that have been made by customers and will enter the system.				1. Type of fish 2. Order quantity
Staff pick up pallets (fish racks) according to the products ordered by consumers				1. Pallet (fish rack) 2. Type of Fish
Daily workers perform the process of checking goods that will go out				Tally Sheet
Officers marginalize fish whose quality is not good / not according to standards				Containers for fish separation
On-demand customer order production process				Order Notes
Complete the process and send the unit out of cold storage.	Finish			Road Letter

The temperature curve is shown in green, while the humidity is shown in pink. The up and down graphs on the temperature and humidity curves when the curve slopes are caused by the opening and closing conditions of the door when loading and unloading goods from the cold storage. The process of deactivating the freezer which automatically activates the heater occurs when the temperature slopes (the formation of ice flowers which then become ice walls and close the evaporator air flow). If the melting of the ice wall by the Heater is exhausted (100% humidity) and wasted, then the freezer starts to be activated again, the temperature will drop sharply until it slopes again. This process cycle occurs repeatedly.

Comparison of Data Logger System Monitoring with Big Data Monitoring System

The monitoring system used is using a data logger device, where the temperature sensor module is installed in the cooling machine room, then after a few days the module is taken, then the raw data is taken and entered into an application that can display a graphical visual form as well as the average temperature calculation (Table-3). According to the data logger used as an auxiliary tool in analyzing the cooling system, data on the system is recorded every 2 to 3 minutes which then the data is downloaded which is displayed in graphical form, only data is taken by the data logger al this is only to meet the requirements of technical audits from independent agencies. So that the consistency of cooling quality according to cooling standards is less considered.

Table-3. Comparison of data logger and big data monitoring system

Item	Data Logger System	Big Data Monitoring System
Data taken	Temperature and Humidity	Temperature and Humidity Temperature
Data capture	Every 15 minutes/1 minute	Every 1 minute
Data collection	Historical data	Near real time
Nature of data	Through a module that is placed on a cooling machine then after a few days it is taken, uploaded to a laptop	The module is permanently installed on the cooling machine, the data sent wirelessly is directly stored in cloud storage
Access monitoring results	Through the dashboard application on a laptop	Through the dashboard application, accessed via the internet
Quality of monitoring results	It is difficult to analyze details because the visual graphics are not smooth.	Big Data, very easy to read its smooth graphical visual display

Performance Analysis of Temperature and Humidity

The cooling performance analysis stage of the cooling machine is monitored for 1 month. Duration for 1 month is done in order to get as much data as possible with various variations of events that arise. The results obtained on several samples of the curve display show that the temperature increase ranges from 2-4°C. The increase in air humidity occurs when the door is opened because the air humidity from outside the cold storage is very high.

The operator activates the defrost when the evaporator is covered by a thick layer of ice (ice flowers). The closure of the evaporator by the ice flower is indicated by the passing of the temperature curve because it is blocked by the ice wall, where the temperature cannot drop any colder. (Figure 4.11) shows the defrost process with intervals of 2 and 4 hours, where the humidity is not high (the formation of ice flowers takes a long time), the temperature will continue to decrease again in other words, activating the defrost longer will cause the temperature to drop even more around - 2 0 C. Monitoring temperature using a data logger pattern cannot be applied properly because the data collection interval is too long and must be uploaded to the application first to analyze.

This can be seen from the monitoring and historical data recorded, from the data it can be seen that the temperature drop is very significant and then slopes down due to ice flowers that quickly form and block the flow of cold air from the evaporator to the cooling machine room. High air humidity causes the formation of ice blossoms that make the walls covered with thick ice and cause the closure of cold air flow in the evaporator. The ice wall will melt during defrost (heater on) and flow to the back of the refrigerating machine room. Storage space humidity that exceeds the relative equilibrium of the material, the material will absorb excess moisture during storage.

Standard Deviation and Percent Error

Analysis of tool accuracy is done by comparing the IoT-based temperature and humidity monitoring tool in the form of a DHT-11 temperature sensor with a standard temperature and humidity monitoring tool in the form of a data logger in the cooling room. The difference value obtained from the test results of comparing the temperature reading value using a temperature and humidity monitoring device using a DHT-11 sensor with a standard temperature and humidity measuring device in the form of a data logger, the minimum temperature difference value is -16 ˚C and the maximum temperature difference value is -3.3 ˚C, while for the IoT module has a minimum value of -16.2 ˚C and a maximum temperature of -3.5 ˚C with a standard deviation of the DHT-11 sensor temperature of 2.26 ° C and an average IoT module of 11.88 ˚C and data logger -11.7 ˚C (Table-4).

Tool Accuracy (%) = 100% - Tool Error (%)
= 100% - 0.74%
= 99,26%

Analysis of tool accuracy is done by comparing the IoT-based temperature and humidity monitoring tool in the form of a DHT-11 temperature sensor with a standard temperature and humidity monitoring tool in the form of a data logger in the cooling room. The difference value obtained from the test results of comparing the temperature reading value using a temperature and humidity monitoring device using a DHT-11 sensor with a standard temperature and humidity measuring device in the form of a data logger obtained a minimum humidity difference value of 76.5% and a maximum humidity difference value of 100% with a standard deviation of the DHT 11 sensor temperature of 6.9047027, while for the IoT module has a minimum value of 76.3% and a maximum value of 99.9% and a standard deviation value of 6.904703 (Table-5).

Table-4. Statistical value of temperature measurement

Description	Modul	Data Logger	% Error
Average	-11.88	-11.70	-8.71
Minimum	-16.20	-16.00	-6.33
Maximum	-3.50	-3.30	-32.14
Standard Deviation	2.26	2.26	44.22

Table-5. Statistical value of humidity measurement

Description	Modul	Data Logger	% Error
Average	89.869	90.069	0.22
Minimum	76.3	76.5	0.26
Maximum	99.9	100.0	0.20
Standard Deviation	6.904	6.904	0.00

Tool Accuracy (%) = 100% - Tool Error (%)
= 100% - 0.17%
= 99.83%

The IoT-based temperature and humidity monitoring tool makes it easier to monitor the cooling warehouse because officers do not need to check the temperature and humidity in the fermentation room manually and no longer need to record temperature and humidity data on the available datasheet paper. The fermentation room supervisor only needs to open the Ubidots website to find out the temperature and humidity of the cold storage, then the data that has been generated will be recorded automatically online to the Ubidots website and can be downloaded anytime and anywhere.

Power Consumption Analysis of Freezer Machine

The fish processing and storage industry on energy use, which is consumed almost used for refrigeration equipment [14]. The energy requirements of fish processing plants mainly come from refrigeration and freezing facilities. The amount consumed for the refrigeration process is about 80%, i.e. for refrigeration facilities and refrigeration compressors for freezing and storing frozen fish.

The defrost process on cooling in cold storage can affect power consumption because the defrost process makes the freezer machine have a pause time to turn off. The existence of this defrost can also make the freezing efficiency maximized because the air temperature is not hampered by ice flowers [15]. Figure-2 to Figure-7 shows that the power consumption of the freezer machine is different for the duration of the defrost process with an interval of 2 hours and defrost with an interval of 4 hours.

Figure-2. Cooling machine power consumption

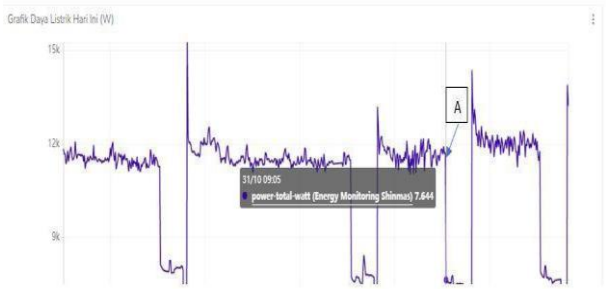


Figure-3. Heater power

Figure-4. Freezer power

Figure-5. Power when the freezer is on

Figure-6. Freezer power off and heater on

Figure-7. Heater power off

Graph (A) shows the power consumed during the defrost process or when the heater is on, i.e. the defrosting process on the evaporator, which has a consumption of 7.64 kW. The freezer power consumption is 11.489 kW (B). The 4-hour defrost interval has only one active heater, while in 4 hours with a defrost interval setting of 2 hours, there are 2 active heaters. After 4 hours, the real active freezer time is 3.5 hours (C & D) and the active heater is 0.5 hours (E & F). So that in a duration of 4 hours the freezer power consumption is as follows:

a. Defrost interval of 2 hours, the consumption is: 2 × 1.5 hours × 11.489 + 2 × 0.5 hours × 7.64 = 44.035 kWh
b. Defrost interval of 4 hours, consumption: 3.5 hours × 11.489 + 1 × 0.5 .hour × 7.64 = 42.107 kWh

So that the application of the defrost process time interval with a period of 2 hours is more efficient in electrical power consumption than the 4-hour one. With savings of (44.035 - 42.107): 44.035 × 100% = 4.37%. The maximum time the cooling machine operates in 24 hours is around 16 hours and the rest for the defrost process to operate is around 8 hours, therefore the defrost period of 2 hours is more efficient [16]. The defrost system at cold storage Jaya Bahari itself is a type of semi-automatic defrost. This defrost system is defrosting carried out by humans and performs functions on the cooling machine automatically and usually this system is only applied to one-door cold storage [17].

CONCLUSIONS

The Standard Operating Procedure (SOP) at cold storage Jaya Bahari consists of several stages including receiving of raw materials, sorting, weighing, preparation in pan, freezing, packaging, storage in cold storage and stuffing that meet good freezing standards and apply the FIFO method in the process of entering and exiting fish products. Furthermore, the performance of the data logger and big data each show results that are not much different with a difference value of 99.26% for temperature measurement and 99.83% for humidity measurement. With a 2-hour defrost, it can save power by 4.37%.

The SOP for fish storage should be adjusted according to applicable standards so that data can be organized properly and improvements need to be made which include supervision of employees and products or raw materials, and company production facilities.

REFERENCES

[1] Clucas, I. J. and Ward, A. R. 1996. *Post Harvest Fisheries Development: A Guide Handling, Preservation, Processing and Quality*. United Kingdom (GB). Natural Resources Institute. 428 pp.

[2] Slamet, G. 2013. Analisis Saluran Distribusi dan Perilaku Konsumen. *Jurnal Mimbar Bumi Bengawan*. 6(13): 40-47.

[3] Gumilang, A. P., Solihin, I., & Wisudo, S. H. 2014. Pola Distribusi dan Teknologi Pengelolaan Hasil Tangkapan Pelabuhan Perikanan di Wilayah Pantura Jawa. *Jurnal Teknologi Perikanan dan Kelautan*. 5(1): 67–76. https://doi.org/10.24319/jtpk.7.67-76

[4] Elmariana,Y., Sumiyanto, W. & Sipahutar, Y.H. 2020. Penetapan CCP dan Persyaratan Dokumen Ekspor Udang Mantis (*Harpiosquilla raphidea*) Hidup. *Seminar Nasional Tahunan XVII Hasil Penelitian Perikanan dan Kelautan.* Departemen Perikanan, Fakultas Pertanian, Universitas Gadjah Mada. 336-347.

[5] Effendi, M.S. 2015. *Teknologi Pengolahan dan Pengawetan Pangan (3rd ed.)*. Alfabeta.

[6] Shabrina, L., & , Widodo Sumiyanto, Hendarni Mulyani, Y. H. S. 2022. Alur Produksi Ikan Layur (*Trichiurus lepturus*) Beku di PT. LPB Belawan-Sumatera Utara. *Prosiding Simposium Nasional Kelautan dan Perikanan*. 9: 213-222.

[7] Arjadi, L., Nuryantoro, N., & Harjanti, D. W. 2018. Evaluasi Cemaran Bakteri Susu yang Ditinjau Melalui Rantai Distribusi Susu dari Peternak Hingga KUD di Kabupaten Boyolali. *Jurnal Ilmu-Ilmu Pertanian*. 13(1). http://dx.doi.org/10.31942/mediagro.v13i1.2146

[8] Prasetyo, D., Abrori, M. Z. L., & Pujianto, A. 2021. Operational of refrigeration machine for cold storage as frozen fish hold in PT. Dwi Bina Utama Sorong. *Buletin Jalanidhitah Sarva Jivitam*. 3(1): 19–27. http://dx.doi.org/10.15578/bjsj.v3i1.10539

[9] Bunnoto, E., Prawatya, Y. E., & Taufiqurrahman, M. 2019. Perhitungan Beban Pendingin pada Cold Storage untuk Penyimpanan Produk Hasil Laut di PT. Xinhaiyuan. *Jurnal Teknologi Rekayasa Teknik Mesin*. 1(1): 1–9.

[10] Priharanto, Y. E., Abrori, M. Z. L., & HS, R. S. 2017. Penilaian Risiko pada Mesin Pendingin di Kapal Penangkap Ikan dengan Pendekatan FMEA. *Jurnal Airaha*. 6(1): 24–32. https://doi.org/10.15578/ja.v6i1.86

[11] Nia Ariani Putri, Zulfatun Najah, Zulmaneri & Taufik Hidayat. 2019. Perancangan SOP (Standar Operating Procedure) Proses Produksi Amplang di Sentra Industri Kecil Hasil Pertanian dan Kelautan (SIKHPK) Teritip, Balikpapan. *Jurnal Teknologi dan Industri Pangan*. 4(2): 57–64. https://doi.org/10.33061/jitipari.v4i2.3147

[12] Moeljanto. 1992. *Pengawetan dan Pengolahan Hasil Perikanan*. Penebar Swadaya. Jakarta.

[13] Budi, D.W.K., Hartati, R.S, & Arjana, I.G.D. 2022. Rancang Bangun Sistem Monitoring Suhu Cold Storage Berbasis IoT Menggunakan Wemos D1 R2 di PT. Aerofood ACS Denpasar. *Jurnal Spektrum*. 9(4): 33–40. https://doi.org/10.24843/SPEKTRUM.2022.v09.i04.p5

[14] Ahadi, K., & Setiadanu, G. T. 2019. Analisis Konsumsi Energi Listrik pada Proses Pembekuan dan Penyimpanan Ikan. *Ketenagalistrikan dan Energi Terbarukan*. 18(1): 11–22.

[15] Darmadi, B., Sofijanto, M. A., Sulistyowati, W., & Rianto, B. 2016. Pemberdayaan UKM pengolah ikan melalui aplikasi *cold chain system* pada produksi ikan olahan bersertifikasi di Kecamatan Paciran, Kabupaten Lamongan Jawa Timur. *Prosiding Semnas Hasil Penelitian*.

[16] Rodlian, R.J.I.J. 2019. Perencanaan Sistem Refrigerasi pada Ruang-Ruang Penyimpanan Kapal Tipe Refrigerated Cargo Ship sebagai Pendukung

Ekspor Buah-Buahan Tropis Indonesia. *Inovtek Polbeng*. 9(2): 362. https://doi.org/10.35314/ip.v9i2.1142

[17] Mandaris, D., & Kusnandar, N. 2014. Analisis Penentuan Waktu Siklus Steady State (SS) dan Defrosting (DF) pada Pengujian Konsumsi Daya Refrigerator mengacu pada Standar CDV IEC 62552 2nd Edition. *Annual Meeting on Testing and Quality*. 146–161.