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Quality Assurance for Frozen Fish (*Decapterus sp*) Utilizing Fault Tree Analysis at PT XYZ (Fish Freezing Company)

Sumartini[1], Putri Wening Ratrinia[2], Nirmala Efri Hasibuan[3], and Wardatul Husna[4]

[1,2,3,4] Program Studi Pengolahan Hasil Laut, Politeknik Kelautan dan Perikanan Dumai, Jl. Wan Amir No.1, Pangkalan Sesai, Dumai, 28824, Indonesia

Abstract. Fish product quality is crucial, and any flaws in frozen fish, such as unpleasant odor, breakage, dents, tears, or texture damage, can negatively impact its overall quality. These defects can lead to reduced customer satisfaction and adversely affect the company's brand reputation. To enhance product quality, the company must establish an efficient quality assurance system and closely monitor the handling of raw materials. The main objective of this practical work is to identify potential risks of damage and develop strategies to prevent such incidents from occurring. The Fault Tree Analysis method is utilized to systematically identify and analyze the root causes of existing errors and find appropriate solutions to address the problem. The FTA results reveal 18 basic event factors that can cause damage to fish, including worker negligence during raw goods placement, inadequate use of plastic protection, lack of rubber carpets in baskets, failure to adjust freezing temperature properly, insufficient inspections, non-compliance with Standard Operating Procedures, improper fish arrangement, excessively hard freezing temperature, employee laziness and carelessness, absence of basket mats, prolonged freezing step, unset temperature checks, mishandling of raw goods due to a rush to finish quickly, and irregular temperature checking schedules. The study aims to understand the step-by-step process of handling flying catfish, identify the factors contributing to fish damage, and analyze the potential damage scenarios.

Keyword: Fish Freezing, FTA, Hazard Risk Analysis, Quality

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1. Introduction

Fish quality refers to the physical condition of the frozen product. Any flaws like odor, cracks, dents, tears, or spoiled texture in the frozen fish can negatively impact its quality. Deficiencies of this nature may result in reduced customer satisfaction and harm the company's image. To improve product quality, businesses need to establish an efficient quality assurance mechanism and carefully oversee raw goods, production stepes, and end products. Employing effective monitoring procedures can decrease flaws in frozen fish and enhance productivity by minimizing damage during the freezing step, such as cracks or tears caused by inadequate inspection and action. Addressing this problem is crucial to comprehend the significance of mitigating fish

*Corresponding author at: [Politeknik Kelautan dan Perikanan Dumai, Jl. Wan Amir No.1, Dumai, 28824, Indonesia]
E-mail address: [tinny.sumardi@gmail.com]

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damage and promoting proper handling, thereby improving product quality, consumer safety, environmental sustainability, and overall economic impact. Achieving this requires cooperation among fishery industry players and the community to ensure the sustainable management of fish resources. The Fault Tree Analysis (FTA) method can be employed to identify the root causes of flawive products. FTA is a well-established and easily understandable method used to evaluate the constraints in various systems [1].

Fault Tree Analysis (FTA) is an approach designed to mitigate specific fault events by creating a logical diagram that includes all the events leading to that particular event. Its purpose is to identify faults comprehensively, taking into account both physical and human factors, and to provide solutions that address the root causes of failures [2]. In the author's practical work, Fault Tree Analysis (FTA) is utilized alongside various other methods, such as FMEA and Lean Six Sigma. By employing FTA, one can gain a clear understanding of how the failure of a component or part can trigger system-wide failures. Consequently, FTA assists in devising effective corrective actions to mitigate the risk of failure.

In the context of frozen fish, product spoilage is a common issue, manifesting as breakage, dents, and tears. By comprehending the primary causes of failure, preventive measures can be identified and implemented. Prior research on the analysis of flaws in the final sanding section at PT. Ebako Nusantara employed FTA and FMEA methods [3]. The study revealed various types of flaws, including wave surfaces, over sanding, cutter marks, gluer marks, and scratches, with corresponding RPN values of 144, 125, 120, 36, and 147, respectively. Further analysis through FTA led to the identification of root causes, prompting recommendations for actions to be taken, such as improving SOPs, installing exhaust fan facilities, and motivating operators through salary incentives [4].

PT. XYZ is a fish freezing company that was established in 2004 and specializes in producing frozen flying fish in plastic packaging. Their distribution network covers local areas, including Jakarta and Pekanbaru. However, the production step has been facing challenges with frequent damage to the frozen fish products, such as breakage, dents, and tears. To ensure the quality of the frozen meat, it is crucial to pay close attention to the freezing temperature, allowing the meat liquid to freeze completely while inhibiting enzymatic, proteolytic, hydrolytic, oxidative, and microbial activities that may cause damage to the meat structure.

To address these issues and improve step capability, it is essential to conduct research and identify the root causes of the problems occurring at PT. XYZ. One effective method that can be employed to analyze and overcome these flaws and damages is the Fault Tree Analysis (FTA) method. Surprisingly, no FTA research has been implemented at PT. XYZ thus far. Implementing FTA could lead to valuable insights and potential solutions to enhance the production step and minimize product damages.

2. Methodology

2.1. Fault Tree Analysis (FTA)

Fault Tree Analysis (FTA) is a visual technique that offers an option to reliability block diagrams, offering a more comprehensive perspective. Unlike reliability block diagrams, FTA follows a top-down, deductive approach that revolves around events rather than individual components. Its key advantage is its focus on failures, which are usually more well-defined compared to non-failures, and there are typically fewer ways for non-failures to occur. The primary objective of FTA is to analyze significant failures or catastrophic events, known as the top event, which is positioned at the top of the fault tree diagram [6]. The fault tree illustrates the relationship between system failures and their underlying causes [7]. It is designed around the peak event, representing the failure of the system. This peak event branches into events that contribute to its occurrence. The branch stops when all the events leading to the peak event are fully explored (Fitria). In the fault tree, symbols represent the relationships between events that are necessary for the top event to occur. The symbols that describe those relationships, namely:

Table 1 The relationship symbols in FTA

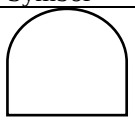
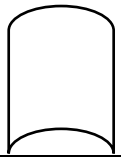
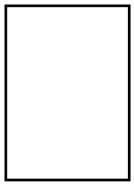
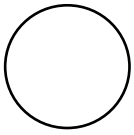
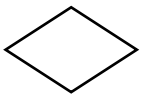
No.	Symbol	Definition
1.		The AND gate symbolizes a situation in which all the events below the gate (input events) must happen simultaneously for the events above the gate (output events) to occur. In simpler terms, the output event will only take place if all the input events happen together
2.		The OR gate indicates a situation where one or more events below the gate (input events) can result in events above the gate (output events). In other words, if at least one of the input events occurs, the output event will also occur.

Table 2 The event symbols in FTA

No	Symbol	Definition
1.		The fundamental component of an analytical tree is the rectangle, which symbolizes a negative event and is commonly located at the tree's top. It may also be positioned at various points along the tree to deindication other events requiring additional elaboration. Within the rectangle symbol, there is a logic gate and an input event below it, representing the factors contributing to the negative outcome. This arrangement facilitates the systematic analysis of failures and helps identify crucial events that necessitate further attention
2.		The circle in the fault tree represents the basic occurrences or basic events. Unlike the rectangle, the circle is situated at the bottom of the fault tree and does not require further elaboration or detailing. It stands as an individual event without any gates or events underneath it. The circle represents the most basic and direct causes or contributing factors to the occurrence of the events represented by the rectangles at the top of the fault tree
3.		The Rhombus symbol is utilized in fault tree analysis to signify portions of the incident or events that have not been completely constructed due to insufficient information or uncertainties. It represents events that are yet to be fully developed within the fault tree, highlighting areas where further investigation or data is needed to complete the analysis accurately. The Rhombus serves as a reminder that additional information is required to understand and assess the potential causes of a specific event or failure

The main objective of this study is to employ Fault Tree Analysis (FTA) as a method for quality assurance of frozen flying fish. The main emphasis is on performing a thorough examination to identify the factors accountable for the decline in frozen flying fish quality. FTA is selected as a valuable tool for risk analysis, aiming to explore the causes of failure and their overall consequences in the system. Through FTA, researchers can precisely determine the particular factors contributing to the reduced quality of frozen flying fish, leading to the implementation of more effective quality assurance measures for this particular product. This approach will enable a thorough understanding of the issues affecting the quality of frozen flying fish, facilitating targeted improvements and ensuring better overall product quality.

2.2. Fault Tree Analysis (FTA) Planning

The next step after analyzing the causes of the observed damage is to implement the Fault Tree Analysis (FTA). FTA serves as a valuable method to identify and prioritize the components in the system that require attention during the maintenance step. This analytical technique allows researchers to investigate the environment and operations to find solutions for the arising problems. The FTA model represents the parallel variations and combinations of errors that may occur due to hardware faults, human errors, or other incidents. It exposes logical causal relationships to pinpoint the main cause of the problem, which is the primary focus of this study [8].

The study centers on the application of Fault Tree Analysis (FTA) for quality assurance in the frozen fish industry. The primary goal is to conduct a comprehensive investigation and identify the factors responsible for quality failures in frozen fish. FTA is a valuable risk analysis tool that allows researchers to scrutinize the causes of failure and their overall effects on the system. Through the use of FTA, specific factors contributing to the decline in frozen fish quality can be precisely identified, thus enabling the implementation of more effective quality assurance measures for this product. The study follows a systematic approach, starting with defining the purpose of utilizing FTA to identify failure causes in frozen fish. Next, it involves identifying the top event (main failure), intermediate events (contributing factors), and basic events (fundamental causes) by investigating equipment damage and conducting company interviews. The fault tree is then created to represent the chain of events leading to the failure, utilizing logic gate symbols to depict relationships between events and causes. This comprehensive analysis is aimed at understanding the root causes of failure and guiding improvements in frozen fish quality assurance.

To carry out this method effectively, a systematic work procedure must be established, outlining the stages of the freezing step from the beginning to the end. The flow diagram of the research step can be used as a reference to follow the steps outlined in the fault tree analysis.

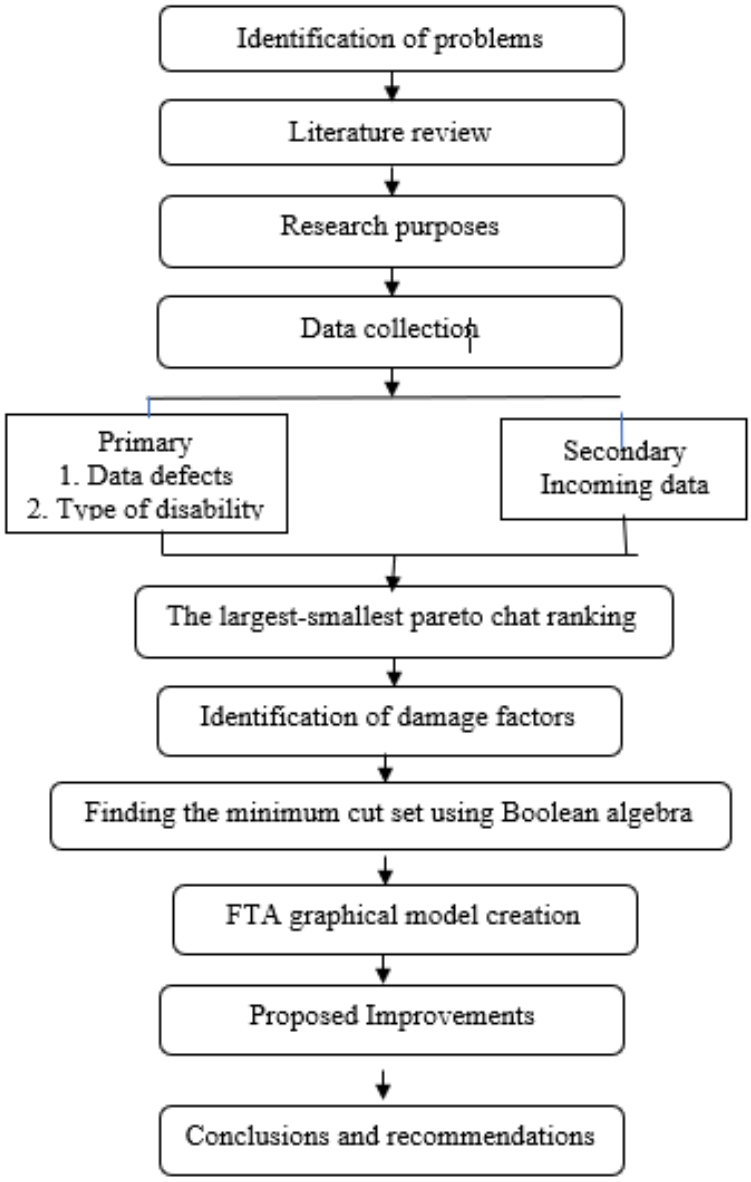


Figure 1. Troubleshooting Steps

Fault Tree Analysis (FTA) involves a systematic six-step step to identify the causes of failures in a system. The step includes understanding the system configuration, generating a logic model, qualitatively evaluating it, analyzing equipment failures and obtaining basic data, performing a quantitative evaluation, and finally recommending appropriate corrective actions. By following this structured approach, FTA provides valuable insights into the root causes of failures, enabling informed decision-making and proactive measures to improve system reliability and performance [9].

3. Result and Discussion

In this section, the results of the research will be discussed and the discussion will be adjusted to previous research if there is relevance to the results of the research. The results of the research steps can be explained in this section.

3.1. Problem Identification

To precisely ascertain the categories of flaws arising during the fish freezing step in March-April, a thorough collection of data is performed from the quality assurance department, alongside conducting interviews and observations. The integration of these information sources results in the identification of different types of flaws, with each flaw being associated with its specific step. The table below provides a comprehensive overview of the flaws and their corresponding stepes.

Table 3 The number of Types of Flaws in Fish Freezing

No	Step Function	Initial Raw Goods (Ton)	Final Raw Goods	Damage Amount (Kg)	Damage Type		
					Wrecked	Broken	Cracked
1.	January	153.050	152.750	300	27	243	30
2.	February	117.400	117.300	100	14	54	32
3.	March	151.800	151.686	114	9	70	35
4.	April	163.120	162.886	234	16	143	75
	Mean	585.370	584.622	748	66	510	172

Based on the table, the freezing step of fish shows differing outcomes each month, leading to varying revenues throughout the month. Daily shipments of fish can reach 5-7 tons, but any damaged fish are segregated and sold as "Pacific" products, representing the damaged goods. Product flaws are defined as products that fail to meet the pre-established quality standards; however, with appropriate rework, they can be economically transformed into a finished product of satisfactory quality. In other words, flawive products do not meet the company's standardized quality expectations, targets, and purposes [10].

The concept of compatibility with quality assumes that there is a range of values accepted for each specification or quality characteristic. To ensure the overall quality of the final product, it is crucial to address and rectify any flaws during the freezing step. By implementing effective quality assurance measures and continuous improvement initiatives, the company can minimize product flaws and enhance customer satisfaction.

3.2. Pareto Chart

The Pareto chart is a visual representation that arranges data categories in descending order from the highest to the lowest rank. It aids in identifying the most critical issues that require immediate attention (highest rank) and those that can be addressed later (lowest rank) (Rachman). By utilizing the Pareto chart, PT. XYZ can pinpoint errors occurring during the fish freezing step and prioritize their resolution based on their significance. The chart presents the problems in a bar graph, highlighting their occurrence in a systematic manner.

Table 4 Number of Flaws and Percentage of Flaws in Frozen Fish Products

No	Flaw Type	Frequency	Cumulative Frequency	Cumulative Percentage	Occurrence Percentage
1	Broken	510	510	68%	68%
2	Cracked	172	682	91%	23%
3	Flat	66	748	100%	9%
	Total	748			

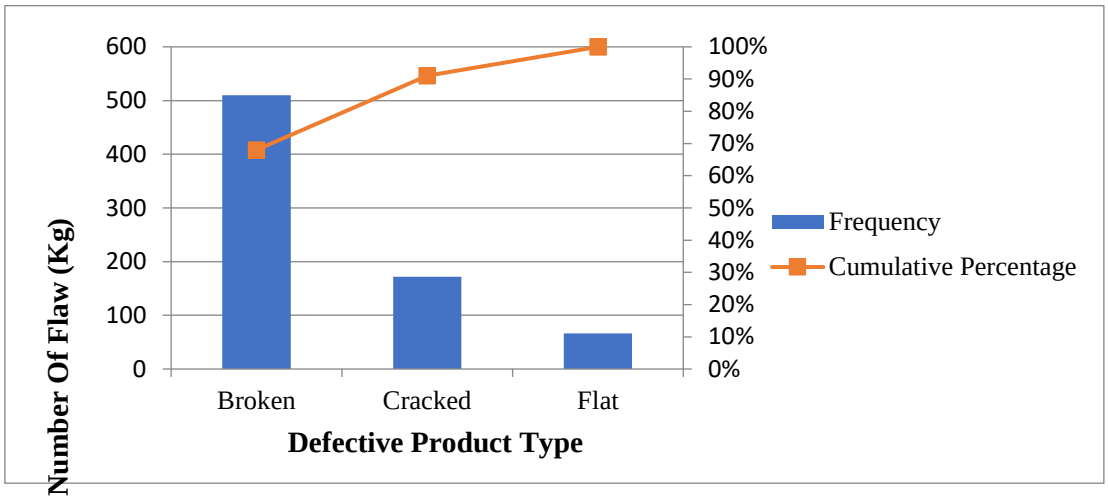


Figure 2. Pareto Chart Based on The Type of Flaws in Fish Freezing.

A total of three flaw types have been identified in the production step. The first type, known as "broken," occurs due to the absence of a rubber carpet backing and negligence by workers. This flaw holds the highest rank, representing 68% of the total frequency of 510 kg from January to April 2023. The second-ranked flaw type is "crack," resulting from excessively high freezing temperatures, accounting for 23% of the total frequency of 172 kg. Given the significant occurrence of the "crack" flaw, falling into the major flaw category, the company should take immediate action to address the factors contributing to this type of flaw.

3.3. Identification of Factors Causing Damage

The primary aim of identifying basic events is to create a comprehensive and well-structured fault tree that illustrates the relationships between various causes, thus identifying potential factors contributing to the damage of frozen fish. Fault-tree diagrams utilize logical operators, mainly the "OR" and "AND" gates. In the case of an AND gate, the output event occurs only when all input events happen simultaneously. This indicates the intersection of sets containing all input events to that specific gate. On the other hand, in an OR gate, the output event occurs if at least one of the input events occurs. This represents the union of sets containing all input events to the gate. By utilizing these logical operators, the fault tree analysis helps in systematically understanding the combinations of events leading to the failure of frozen fish [11]. The following is a fault tree of flaws in process that will be analyzed.

1. Faulty fracture in fish

The predominant failures observed in this step primarily revolve around broken fish occurrences. These flaws, which include fractures in the fish, are a result of employee actions during the handling of raw goods. These actions include climbing on the baskets, stepping on frozen fish, and throwing raw goods, leading to fractures in the fish. To address the issue of broken fish, several corrective measures can be implemented. Firstly, employees should be instructed not to climb the baskets and to handle the fish beside the basket to minimize damage. Secondly, when placing fish in the baskets, they should be done slowly and carefully to prevent any deterioration in quality. Additionally, each basket should be equipped with a rubber carpet base to provide

support and prevent damage. Regular checks should be carried out by employees to ensure that the fish has a proper base in the basket to avoid breakage caused by the iron basket. These measures can help reduce the incidence of flaws, specifically broken fish, and improve the overall quality of the frozen fish production step.

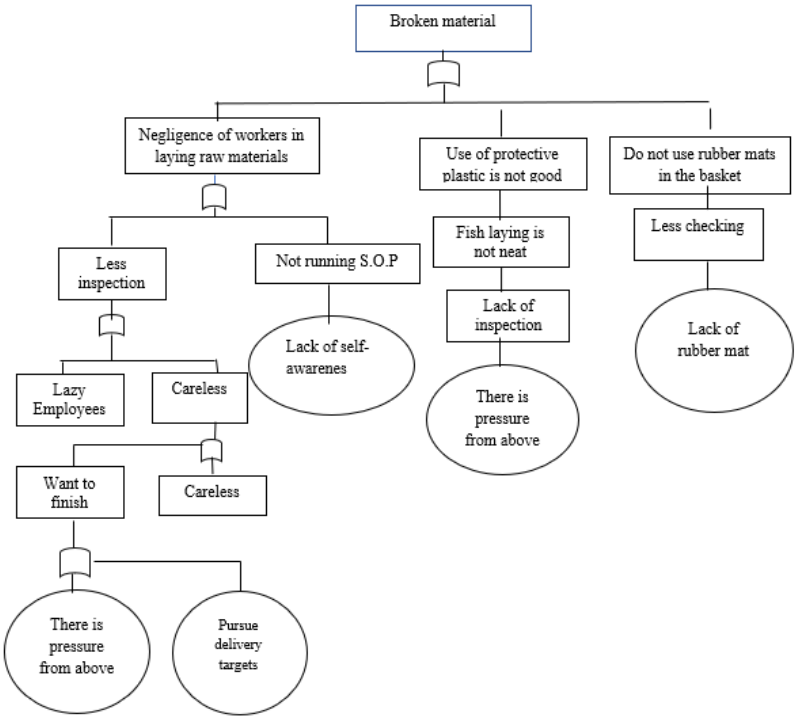


Figure 3. Fracture Flaws in Fish

2. The disability of the wrecked fish

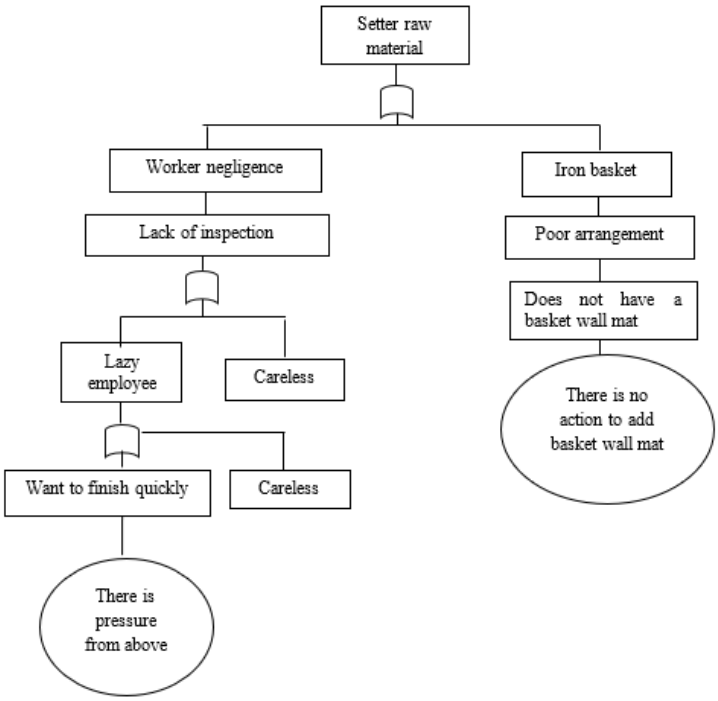


Figure 4. The Disability of the *Penyet* (wrecked) Fish

The failures observed in this step mainly involve the occurrence of *penyet* fish, which is caused by employees placing the raw goods too tightly, resulting in the fish getting squashed against the sides of the iron basket. To prevent this flaw and ensure that the fish is not damaged, employees should handle the fish with care and avoid collisions with the sides of the basket. They should also be mindful of not packing the raw goods too densely. Another solution is to line the gaps of the iron basket with a rubber carpet to create a buffer and prevent the fish from getting squashed. Additionally, employees should check whether the basket already has a carpet mat before placing the fish, as this will further prevent any sinking or squashing of the fish due to collisions with other raw goods. Implementing these measures will help to reduce the incidence of flaws, specifically "penyet" fish, and maintain the overall quality of the frozen fish production step.

3. Torn Fish Disabilities

The failures observed in this step involve "tearing" in the fish products. This flaw occurs due to the actions of employees when taking raw goods, where they step on the raw goods, resulting in tears in the fish. Additionally, during the freezing step, the fish may also experience tearing due to the room temperature being too high and the freezing step being too prolonged, causing damage to the fish products.

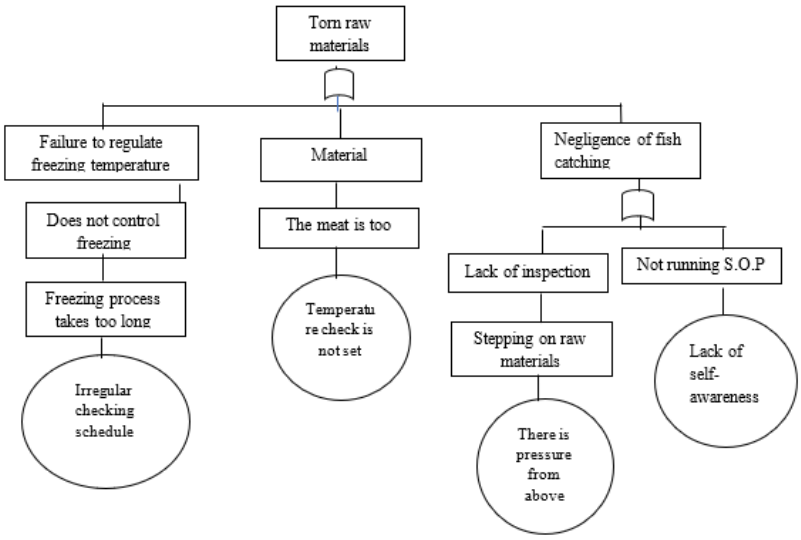


Figure 5. Torn Fish Disabilities

To prevent these flaws from occurring in the fish products, employees should adopt certain measures. When taking raw goods, employees should handle them carefully and avoid stepping on them to prevent tearing. Instead, they should take the raw goods beside the basket to minimize any potential damage.

During the freezing step, employees must pay close attention to the temperature to ensure it is appropriate. If the freezing temperature is too high, it can lead to flaws in the fish products. Therefore, employees should regularly check the temperature during the freezing step and make sure it is not too high or too low. By implementing these measures, employees can effectively

reduce the occurrence of "tearing" flaws in the fish products and maintain the overall quality of the production step.

3.4. Determination of The Minimum Cut Set

Once the Fault Tree Chart for each flaw is constructed, the subsequent step involves identifying the minimum cut set to determine the root cause of the flaws in the fish freezing step. This is accomplished through a qualitative analysis utilizing Boolean Algebra, a mathematical approach employed to simplify or decompose complex logic circuits into more manageable ones. The minimum cut set is computed in the fault tree chart presented below. This analytical step aids in identifying the critical combinations of events or failures that lead to the occurrence of the flaws in the fish freezing step, helping to prioritize and address the most significant root causes for quality improvement and preventive measures.[12].

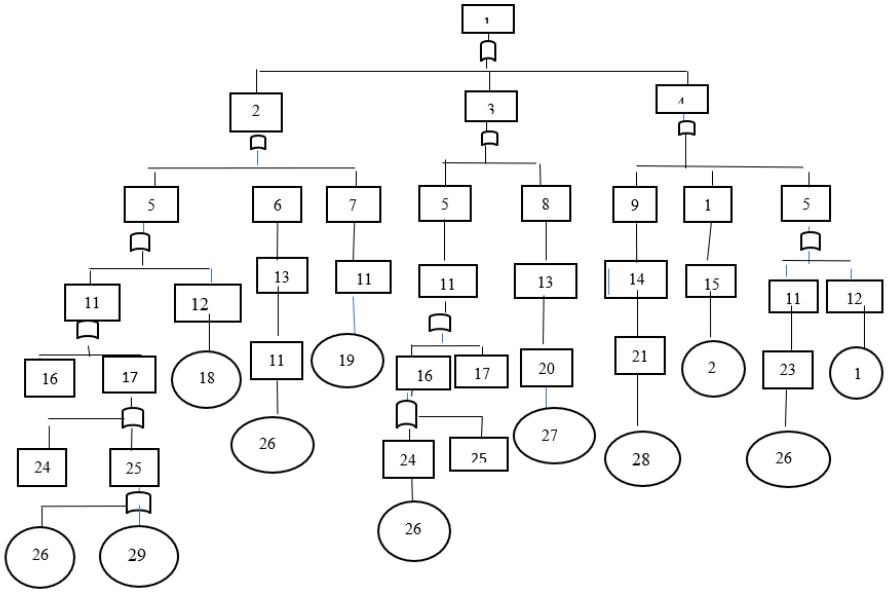


Figure 6. Flow Chart *Fault Tree*

Table 5 Information from the image above is explained in the table below

NO	Indication	NO	Indication
1	Raw goods damage	16	Lazy employee
2	Broken goods	17	careless
3	Flattened raw goods	18	Lack of self-awareness
4	Torn raw goods	19	Lack of rubber carpet underlay
5	Negligence of workers in laying raw goods	20	Does not have a base basket
6	Use of protective plastic is not good	21	The step of freezing fish is too long
7	Do not use rubber mats in baskets	22	Temperature check is not set
8	Iron basket	23	Stepping on raw goods
9	Failure to regulate freezing temperature	24	Want to finish quickly
10	goods	25	Careless
11	Lack of inspection	26	There is pressure from above
12	Not running SOPs	27	There is no action to add wall mats
13	Fish laying is not neat	28	Irregular temperature checking schedule
14	Does not assurance freeze temperature	29	Chase the target sender
15	The meat is too tough		

The process of determining the minimum cut set:

Top level = 1

= 2 + 3 + 4

= [5 + 6 + 7] + [5 + 8] + [9 + 10 + 5]

= [11 + 12 + 13 + 11] + [11 + 13] + [14 + 15 + 11 + 12]

= [16 + 17 + 18 + 11 + 19] + [16 + 17 + 20] + [21 + 22 + 23 + 18]

= [(24 + 25) + 18 + (19)] + [24 + 25 + 27] + [(28) + 22 + (26) + 18]

= [(26 + 29) + 18 + 26 + 19] + [(26) + 27] + [28 + 22 + 26 + 18]

Based on the determination of the minimum cut set, the basic events that can cause flaws in freezing fish are as follows:

Table 6 The result of the breakdown of the method *Fault Tree Analysis*

No	Codes	Indication	No	Codes	Indication
1	Codes 5	Negligence of workers in laying raw goods	11	Codes 17	Careless
2	Codes 6	The use of protective plastic is not good	12	Codes 20	Does not have a basket bottom
3	Codes 7	Do not use rubber mats in the basket	13	Codes 21	The step of freezing fish is too long
4	Codes 9	Failure to regulate the freezing temperature	14	Codes 22	Temperature check is not set
5	Codes 11	Lack of inspection	15	Codes 23	Stepping on raw goods
6	Codes 12	Not running SOPs	16	Codes 24	Want to finish quickly
7	Codes 13	Less neat placement of fish	17	Codes 27	There is no action to add wall mats
8	Codes 14	Does not assurance freeze temperature	18	Codes 28	Temperature checking schedule is not set
9	Codes 15	The meat is too tough			
10	Codes16	Lazy employees			

The implementation of the Fault Tree Analysis (FTA) method has yielded 18 basic events that have the potential to cause damage during the fish freezing step. Through this FTA method, it becomes feasible to identify the key factors that contribute to the occurrence of flaws in the fish freezing step. By pinpointing these crucial causes, targeted improvements can be made to enhance the overall freezing step of the fish.

The application of the FTA method provides valuable insights into the root causes of the flaws, enabling more focused and effective strategies for addressing and mitigating potential issues in the fish freezing step. This systematic approach facilitates the enhancement of product quality and step efficiency, contributing to the overall improvement of the fish freezing operations.

3.5. Suggested Enhancements

The suggested enhancements for enhancing the FTA analysis (Fault Tree Analysis) results are outlined below:

Table 7 Suggested Enhancements

No	Damaged Reason	Causative factor	Suggested Enhancements	Assurance Measures
1.	Men	➢ Careless ➢ Lazy Employees ➢ Employee Negligence ➢ Raw Goods Trampling	➢ To offer assistance, direction, and motivation to employees in order to help them overcome carelessness. ➢ To find the appropriate solution, engage in effective communication with the employees and thoroughly discuss the matter. ➢ To cultivate a responsible attitude towards their work. ➢ To improve the supervision of employees during the step of stamping raw goods.	➢ Offering solutions that promote diligence in work and implementing sanctions for employees who exhibit carelessness. ➢ To prevent errors and decrease negligence, enforce sanctions against employees who display laziness or carelessness. ➢ To prevent errors and minimize negligence, enforce sanctions against employees who demonstrate carelessness. ➢ To increase the level of supervision over employees.
2.	Goods	➢ Protective Plastic ➢ Iron Basket	➢ To include Penking packaging for products that are packed in a master carton. ➢ To include rubber carpet mats as a preventive measure against damage.	➢ In case of damage, promptly replace it with new packaging goods. ➢ If the rubber carpet mat is insufficient, consider adding or purchasing a new one. ➢ To reduce the freezing temperature and avoid excessively prolonged freezing.
3.	Methods	➢ The fish meat is excessively firm.	➢ To inspect raw goods during the freezing step. ➢ Perform fish repairs.	
4.	Machines	➢ Error Machine ➢ Unstable temperature	➢ Check the freezing machine every hour.	➢ If the freezing machine becomes irreparable, replace it with a new one.

4. Conclusion and Future Research

The study on fish freezing damage utilizing the Fault Tree Analysis method uncovered the existence of three distinct types of flaws in the step at PT XYZ. These flaw are caused by various factors, including negligence of workers during raw goods laying, inadequate use of protective goods, lack of rubber mats in the baskets, failure to follow Standard Operating Procedures (SOP), and insufficient temperature assurance, among others. To improve the step and minimize flaws, it is essential to implement stricter supervision of employees to prevent mishandling of raw goods and equipment. By addressing these factors, PT XYZ can enhance the quality of their frozen fish products and optimize their overall operational efficiency.

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REFERENCES

[1] S. Kabir, "An overview of fault tree analysis and its application in model based dependability analysis," Expert Syst. Appl., vol. 77, pp. 114–135, 2017, doi: 10.1016/j.eswa.2017.01.058.

[2] T. Rachman and A. Septianto, "Usulan Penggunaan Metode Fault Tree Analysis untuk Penurunan Kecelakaan Kerja pada PT. Inoac Polytechno Indonesia," J. InovisiTM, vol. 11, no. 1, pp. 45–51, 2015.

[3] M. F. Prayogi, D. P. Sari, and A. Arvianto, "Analisis Penyebab Cacat Produk Furniture Dengan Menggunakan Metode Failure Mode And Effect Analysis (FMEA) Dan Fault Tree Analysis (FTA) (Studi Kasus Pada Pt. Ebako Nusantara)," Ind. Eng. Online J., vol. 5, no. 4, pp. 343–354, 2016, [Online]. Available: https://ejournal3.undip.ac.id/index.php/ieoj/article/view/14113

[4] Y. Alfianto, "Analisis Penyebab Kecacatan Produk Weight A Handle Menggunakan Metode Fault Tree Analysis dan Failure Mode and Effect Analysis sebagai Rancangan Perbaikan Produk," JIEMS (Journal Ind. Eng. Manag. Syst., vol. 12, no. 2, pp. 71–80, 2019, doi: 10.30813/jiems.v12i2.1493.

[5] S. Widati, "Pengaruh lama pelayuan, temperatur pembekuan dan bahan pengemas terhadap kualitas kimia daging sapi beku The," J. Ilmu dan Teknol. Has. Ternak, vol. 3, no. 1, pp. 52–58, 2008.

[6] L. Y. Waghmode and R. B. Patil, "an Overview of Fault Tree Analysis (Fta) Method for Reliability Analysis," J. Eng. Res. Stud. , vol. IV, no. I, pp. 06–08, 2013, [Online]. Available: http://en.wikipedia.org/wiki/Reliability_%28engineerin

[7] T. Ferdiana and I. Priadythama, "Analisis Flaw Menggunakan Metode Fault Tree Analysis (FTA) Berdasarkan Data Ground Finding Sheet (GFS) PT. GMF AEROASIA," Pros. Semin. Nas. Ind. Eng. Conf. 2016, pp. 1–8, 2015.

[8] W. Y. Kartika, A. Harsono, and G. Permata, "Usulan Perbaikan Produk Cacat Menggunakan Metode Fault Mode and Effect Analysis dan Fault Tree Analysis Pada PT. Sygma Examedia Arkanleema," J. Online Inst. Teknol. Nas., vol. 4, no. 1, pp. 345–356, 2016.

[9] D. Q. Li, S. H. Jiang, Y. F. Chen, and C. B. Zhou, "System reliability analysis of rock slope stability involving correlated failure modes," KSCE J. Civ. Eng., vol. 15, no. 8, pp. 1349–1359, 2011, doi: 10.1007/s12205-011-1250-5.

[10] I. G. Sihombing and D. Pujotomo, "Analisis Penyebab Flaw dengan Menggunakan Metode Failure Mode Effects and Analysis dan Fault Tree Analysis pada Assembly Area PT Ebako Nusantara," Ind. Eng. Online …, 2019.

[11] A. Nouri.Gharahasanlou, A. Mokhtarei, A. Khodayarei, and M. Ataei, "Fault tree analysis of failure cause of crushing plant and mixing bed hall at Khoy cement factory in Iran," Case Stud. Eng. Fail. Anal., vol. 2, no. 1, pp. 33–38, 2014, doi: 10.1016/j.csefa.2013.12.006.

[12] N. . Widjanarka, "Teknik Digital," 2006.