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Risk Analysis of Blackspot and Blacktail Defects in the Production Process of Frozen Vannamei Shrimp (*Litopenaeus vannamei*)

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Abstract
Vannamei shrimp (*Litopenaeus vannamei*) is one of the fishery commodities that has high economic value both in the domestic and global markets. The complexity of the long and multi-party frozen vannamei shrimp production process and the uncertainty of the characteristics of the raw materials make these conditions vulnerable to a risk of product quality degradation. The purpose of this research is to identify, analyze and provide risk control proposals to overcome potential hazards or sources of risk in order to minimize quality degradation that is detrimental to the company. The quality decline referred to in this study is defects in products, one of which is defects in blackspots and blacktails in frozen shrimp products. The research method used is qualitative with a quantitative approach and research data collection methods through field observations, interviews and questionnaires. Sampling was done using purposive sampling techniques. Risk measurement and evaluation analysis uses the Failure Mode and Effect Analysis (FMEA) method to determine the severity, occurrence and detection level, so that the Risk Priority Number (RPN) and Risk Value Score (RSV) values are obtained which can determine the priority of potential hazards or risk sources of blackspot and blacktail defects that must be prioritized for repair. As a result of the risk identification, there are 21 potential hazards or risk sources that cause blackspots and blacktails in products. Through the pareto diagram, it is known that there are 12 potential hazards that have RPN and RSV values that exceed critical RPN and RSV values. Through the fishbone diagram, 2 potential hazards / sources of risk are determined to be blackspot and blacktail defects which are the priority of risk management with an RPN value of 225.46 and an RSV value of 54.66 for the machine risk category on the potential danger of temperature in cold storage that is not optimal so that the minimum standard storage temperature in cold storage is not achieved. In the risk category of man or employee for potential dangers, the quantity of storage in cold storage exceeded the standard limit with an RPN value of 206.59 and an RSV value of 48.61. Risk control is carried out in a mitigated and preventive manner, at each source of risk.

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Keywords: Vannamei Shrimp, Blackspot/Blacktail, Risk Analysis, FMEA

1. Introduction

Litopenaeus vannamei or also known as vannamei shrimp has significant economic value because it is popular in the global market, especially in the seafood industry. In the Regulation of the Minister of Maritime Affairs of the Republic of Indonesia Number 24 of 2021 concerning the Preparation of the Fishery Commodity Balance and the Distribution of Fishery Commodity Import Allocation, it is explained that (Menteri Kelautan dan Perikanan, 2021) fishery products are fish that are handled, processed, and/or made into final products in the form of live fish, fresh fish, frozen fish and other processed fish.

The complexity of the production process involving many parties and the many uncertainties of the quality characteristics of raw materials in the acceptance of raw materials are challenges in processing frozen shrimp production. This condition is vulnerable to a risk that has an impact on the business process in the fishery product processing company. Risk is the possibility of potentially adverse events or uncertain circumstances that a person or company faces and can have a detrimental impact (Kountur, 2006; Squirrelly 2011 as cited in Lindawati & Rahadian Rikrik, 2016) [5]. The success or failure of a production process will not be separated from the risks inherent in each activity.

A decrease in shrimp quality is an example of risks that may arise in the production process both during the stage of receiving raw materials, during the production process and storage in cold storage. Parameters that can be observed on the quality of shrimp, both the quality of raw materials from the supplier, during the production process, and in the final product to the time of storage in cold storage are product defects or physical damage/defects found in shrimp.

It is important for companies to have a good risk assessment, because many large companies that fail to carry out risk management suffer both material and non-material losses. According to (Darmawi, 1994) as cited in Hasanah *et al*., 2018) [4], risk is a deviation of actual results from expected results. Risk management is an effort to know, analyze and control risks in every company activity with the aim of obtaining higher effectiveness and efficiency

This research was carried out in stages in one of the fish processing units with vannamei shrimp commodities located in Sidoarjo. Starting with identifying risks and analyzing the risk of quality degradation in the form of defective or defective products from various production process activities from the stage of receiving raw materials to storage in cold storage. Furthermore, the data and information obtained are analyzed to formulate risk control recommendations that need to be carried out to prevent a decline in the quality of frozen vannamei shrimp products. The risk analysis of quality degradation in the production process is very important in the frozen vannamei shrimp processing business to minimize the possibility of production failure in the processing unit. With the implementation of good risk management in frozen shrimp processing, the effectiveness of shrimp resource utilization can be increased, while reducing waste that has an impact on the environment. This supports the creation of a more efficient and sustainable production process. Therefore, information related to the amount of risks faced in the frozen vannamei shrimp processing business is quite important to explore, because it can help decision-makers to design policies that can facilitate fishermen's business by reducing their business risks.

This study aims to identify the hazards that result in the risk of quality degradation in the frozen vannamei shrimp production process, analyze the level of risk from these potential hazards and develop risk management strategies (risk control) that need to be carried out to prevent quality degradation in the frozen vannamei shrimp production process.

This study utilized various tools and materials necessary for collecting data and information related to the stages of the frozen vannamei shrimp production process, types of defects in frozen vannamei shrimp products, potential hazards or risk sources of each defect, risk level for each potential hazard or source of risk and risk control.

- Questionnaires and observation forms
- Writing tools for recording data obtained during the research
- A laptop for processing the data collected during the research.

2. Research method

The method used in this study is a qualitative method with a quantitative approach. Sampling or selection of respondents in this study uses the purposive sampling technique or deliberate selection of research respondents, namely only parties involved in the production process and have the authority of the decision-maker who is appointed to be the respondent in this study. There are 17 people who have responsibility for the production process, then 8 respondents are selected including 2 people who are authorized to make decisions on the course of the production process.

The method of data collection is through field observation, interviews and questionnaires, in this study, the data collected consists of two types, namely primary data and secondary data. Primary data is information obtained directly from the source through a data collection method specifically designed for this research. Primary data collection was carried out through interviews with the Quality Assurance Manager and direct observation at the location of the frozen vannamei shrimp processing unit to observe the flow of the frozen vannamei shrimp production process, defects in the product and the source of risk or potential danger. The questionnaire is also used as a tool to collect data from respondents, in the form of an assessment of potential hazards or risk sources of defects in blackspots and blacktails on products during the production process. Secondary data is information that already exists and has been collected by other individuals or institutions, which can be used to support this research. Secondary data was obtained through a literature review, including documents, articles, and books relevant to the research topic, as well as a recap of product finish defect data monitored by quality control during July to September which provided information on the percentage of defects in product finishes during the research period. By combining these two types of data, this study is expected to be able to provide a more comprehensive picture of the potential hazards or sources of risk of product defects in the processing process of frozen vannamei shrimp, risk analysis and risk control.

The data analysis of this study used the FMEA method, through a questionnaire the values of Severity (S), Occurrence (O) and Detection (D) were obtained for each potential hazard or source of risk in blackspot and blacktail defects. The next stage is to calculate RPN and RSV values and risk control recommendations through pareto charts and fishbone charts that can determine the priority of potential hazards or risk sources that must be prioritized for repairs.

3. Results and Discussion

The stages in the production process of frozen vannamei shrimp include:

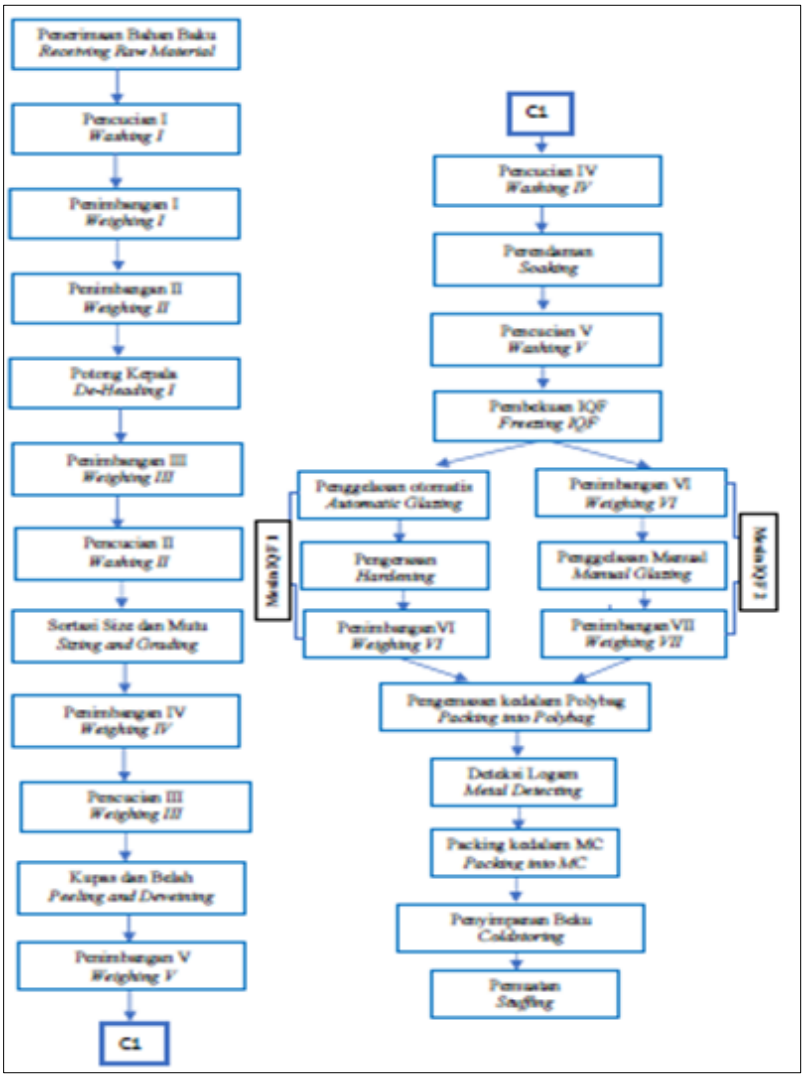

Fig 1: Frozen Vannamei Shrimp Production Process Flow Diagram

1. Receiving of raw materials

It is the initial stage of the process of receiving raw materials from suppliers. Before the shrimp is dismantled, sulfites and antibiotics are checked by the internal lab, if the test results are according to the specifications, the shrimp is accepted. Then Quality Control (QC) will conduct an organoleptic check first, if the average organoleptic value is ≥ 7, then the shrimp is received and dismantled for the production process. At this stage, the count/lbs, product defects and foreign materials that may have been carried from the suplayer on the Head On Vannamei are checked.

2. Deheading

The stage of separating the shrimp head and cleaning the shrimp genjer. At this stage, checks are carried out by the QC line to calculate count/lbs, uniformity (UR), product defects and foreign materials on Headless vannamei.

3. Sizing dan grading

It is a stage of separation of the size and grade of vannamaei shrimp according to the buyer's specifications. At this stage, the QC line checks to ensure that the count/lbs, uniformity and defect of the product are in accordance with the product specifications. If there is a discrepancy, a manual sorting of the product is carried out.

4. Peeling and Deveining

At this stage, the shrimp is peeled and split to clean the intestines according to the buyer's specifications. Qc line checks the count/lbs, UR and defects of the product as well as foreign materials on the product.

5. Soaking

It is the stage of soaking products with food additives, the type of food additive and the length of soaking time is adjusted to the buyer's specifications. Product monitoring by the QC line in this area is checking count/lbs, UR, product defects and product appearance during the soaking stage. Because the characteristics of raw materials are different and the response to the soaking process is also not the same.

6. Freezing IQF

The last stage in the production process is the freezing of products using the Individual Quick Freezing (IQF) freezing method, which is the freezing of shrimp individually or arrangement one by one when entering the freezing machine. The temperature of the shrimp core is at least -19±2°C, after it comes out of the freezing machine, then the shrimp is glazed (a layer of ice to maintain the natural moisture of the shrimp). The packaging stage is carried out after the shrimp pass through the hardener machine, weighing and passing the metal detector.

7. Storage in coldstorage

After going through such a long production process, then the shrimp that have been packaged in a master carton will be stored in cold storage. The ideal temperature in cold storage is -21±2°C. Temperature control by installing a data logger in cold storage that is regularly checked by QC.

At each stage of the production process except the IQF stage to maintain the cold chain of the product, the ideal temperature of the shrimp is ≤5°C. Temperature monitoring is carried out by QC.

Defects are nonconformity in the product that can cause a decrease in the quality or quality of the product so that it affects the acceptance of the buyer. Blackspot is a defect in shrimp where the skin of the shrimp is blackened in some cases can penetrate to the meat. While blacktail is the skin of the tail that is blackened and some are found to penetrate to the flesh.

Fig 2: Blackspot and Blacktail Defects in Vannamei Shrimp

The deterioration of shrimp quality is closely related to the appearance of black color found in the shrimp carapace. The color reaction that occurs is the formation of black, which is called blackspot (Haard & Simpson, 2000 as cited in Sipatuhar *et al*., 2020) [9].

Blackspot and blacktail defects are the impact of cold temperature failures on shrimp that are not maintained either due to product handling errors or damage to the refrigeration engine in the vehicle during the distribution stage and during the cold storage period. This can be avoided if the cold chain is maintained from the time of the harvesting process, distribution from the pond to the processing unit to the processing and storage process.

The first step in the risk analysis of quality degradation in the production process of frozen vannamei shrimp is to determine the sources of risk or potential hazards that cause product defects (risk identification) is to group between the type of defect and the potential hazard or risk source that causes degradation or defects in the product.

Table 1: Potential Hazards or Risk Sources and Risk Categories of Blackspot / Blacktail Defect

Category Risk	Potential Hazard / Risk Sources
Material or environment	1. Organoleptic value at the acceptance of raw materials at the minimum acceptance limit
	2. Raw material characteristics do not withstand standard soaking process
Man or employee	3. The production quantity is less than the acceptance of raw materials so that raw materials are temporarily accommodated before the soaking stage
Machine or equipment	4. Cold chains in shrimp during the production process are not maintained
	5. Inaccuracy of QC (Quality control) in product quality sampling
	6. The team leader is not thorough in correcting the work of the employees
	7. How to accommodate shrimp is not up to standard
	8. Wholesale employee error in applying the work procedures of cutting head, manual sorting, peeling, freezing and packaging
	9. The temperature of the soaking solution when the stirring process is too high
	10. Too long stirring time
	11. The work speed of employees is slow or the number of employees is not proportional to the workload, so that the goods that have been frozen accumulate at the stages of weighing, packaging into polybags and the polybag sealing process
	12. The storage quantity in cold storage exceeds the standard limit
	13. How to arrange master carton in cold storage is not up to standard
	14. The temperature of the production chamber exceeds the maximum limit of the ideal temperature
	15. The accuracy of the scales has not been calibrated so that if there is an indication of problems with the scale as a measuring tool, it affects the sampling of the percentage of defects in shrimp

	16. Damage to the soaking machine results in limited working capacity in the soaking area , so that the reservoir before soaking accumulates 17. Damage to the cooling engine so that the engine speed or temperature is not optimal 18. The minimum core temperature in shrimp after freezing is not achieved 19. The minimum core temperature in shrimp after hardening is not achieved 20. The sealing machine experienced problems so that the sealing process ran slowly causing a buildup of products resulting in a decrease in shrimp temperature 21. The temperature in cold storage is not optimal so that the minimum temperature of the standard storage in cold storage is not reached

Identification of potential hazard risks or sources of risk in blackspot and blacktail defects is obtained through field observation and interviews with the Quality Assurance Manager. There are 21 potential dangers or sources of risk of defect blackspot and blacktail in the production process of frozen vannamei shrimp.

The quantitative analysis in this study is by the FMEA (Failure Mode and Effect Analysis) method, in this study using the FMEA Process (PFMEA) method to detect risks that have been identified during the process. Identification of product failures in the form of product defects is carried out by assigning a score or score of each potential hazard or risk source based on the level of occurrence, severity, and detection level.

Through field observation and interviews, data was obtained on the stages of the production process and the risks that may occur, one of which is a decrease in shrimp quality. The data is then used as attributes in the questionnaire, the purpose of the questionnaire is to determine the severity, occurrence and detection values in the production process.

These values (severity, occurrence, detection) will be used to provide an assessment of the risks that occur in the production process.

1. Severity Assessment

Assessment the impact in this study is a defect that arises due to a potential hazard or source of risk that occurs. The severity value was obtained through a questionnaire that had been carried out on the parties involved in the production process. This value is the severity of a potential hazard or source of risk that results in an impact in the form of a defect blackspot or blacktail on the product.

Table 2: Severity (S) Rating Scale

Result	Scale	Criterion
No consequences	1	No effect on quality
Very little consequence	2	Disturbed raw material characteristics
Few consequences	3	The result is small to the quality of the raw materials
The consequences are small	4	The quality of raw materials is slightly disturbed
Quite consequential	5	Failure results in some dissatisfaction with the quality of raw materials
Quite consequential	6	Failure results in discomfort
The consequences are great	7	The quality of raw materials is unsatisfactory
Extreme	8	The quality of raw materials is very unsatisfactory
Serious	9	Potentially causing adverse effects on the production process in fertilizer manufacturing
Risk	10	The effect of failure in the quality of raw materials results in imperfect production processes

***Source*:** (Fathurrozi *et al*., 2021) [3]

2. Occurrence Assessment

The assessment of occurrence is carried out to find out how often a product defect is likely to occur in the production process. The occurrence assessment is carried out by giving a score from 1 to 10 to find out how often potential hazards or sources of risk of product blacktail defects and blackspots in the production process are likely to occur.

Table 3: Occurrence (O) Rating Scale

Probability of Risk Occurrence	Description	Peringkat
Very high	Frequent	10
Tall	Recurring	9
		8
		7
Keep	Rare	6
		5
		4
Low	Very small happens	3
		2
Very low	Almost never happens	1

Source: (Pamungkas *et al*., 2019) [7]

3. Detection Assessment

Detection is an assessment of the level of detection in finding potential hazards or risk sources that cause defect blackspots and blacktails in products.

Table 4: Detection (D) Rating Criteria

Detection	Possible Detection	Peringkat
Almost impossible	The controller cannot detect the failure	10
Very rare	It is very likely that the controller will find a potential failure	9
Infrequently	It is rare that the controller will find a potential failure	8
Very low	The likelihood of controllers detecting failures is very low	7
Low	Controller probability for detecting low failures	6
Keep	Controller's ability to detect moderate failures	5
Rather tall	The possibility of controllers to detect failures is rather high	4
Tall	Controller possibilities for detecting high failures	3
Very high	The possibility of controllers detecting failures is very high	2
Almost certainly	Failures in the process cannot occur because they have been prevented through the design of the solution	1

Source: (Pamungkas *et al*., 2019) [7]

4. Risk Priority Number (RPN) and Risk Value Score (RSV)

After the severity, occurrence, and detection values are given, each value will be multiplied so that a Risk Priority Number

(RPN) value is obtained. These values are used to compare the causes identified during the analysis of each potential problem.

RPN = Severity (S) x Occurrence (O) x Detection (D)

As for the critical RPN value, it can be calculated with the formula

$$\text{critical RPN} = \frac{\text{total RPN}}{\text{jumlah Risiko}}$$

RiskValue Score (RSV) is used to rank potential risk sources.

RSV = Severity x Occurrence

Critical RSV values can be obtained by formula calculation

$$\text{critical RSV} = \frac{\text{total RSV}}{\text{jumlah Risiko}}$$

Table 5: Risk Assessment with FMEA on Blackspot and Blacktail Defect Types

No.	Potential Hazard / Risk Sources	S	O	D	RPN	RSV
1	Organoleptic value at the acceptance of raw materials at the minimum acceptance limit	6.250	4.750	3.625	107.62	29.69
2	Raw material characteristics do not withstand standard soaking process	6.000	4.875	4.500	131.63	29.25
3	The production quantity is less than the acceptance of raw materials so that raw materials are temporarily accommodated before the soaking stage	5.750	5.875	3.375	114.01	33.78
4	Cold chains in shrimp during the production process are not maintained	6.875	6.625	3.125	142.33	45.55
5	Inaccuracy of QC (Quality control) in product quality sampling	7.500	4.875	4.375	159.96	36.56
6	The team leader is not thorough in correcting the work of the employees	6.375	6.750	4.000	172.13	43.03
7	How to accommodate shrimp is not up to standard	7.500	5.000	3.375	126.56	37.50
8	Wholesale employee error in applying the work procedures of cutting head, manual sorting, peeling, freezing and packaging	6.875	5.000	4.500	154.69	34.38
9	The temperature of the soaking solution when the stirring process is too high	7.750	6.250	3.375	163.48	48.44
10	Too long stirring time	7.250	5.625	4.125	168.22	40.78
11	The work speed of employees is slow or the number of employees is not proportional to the workload, so that the goods that have been frozen accumulate at the stages of weighing, packaging into polybags and the polybag sealing process	5.875	6.500	4.500	171.84	38.19
12	The storage quantity in cold storage exceeds the standard limit	7.625	6.375	4.250	206.59	48.61
13	How to arrange master carton in cold storage is not up to standard	7.375	6.000	4.375	193.59	44.25
14	The temperature of the production chamber exceeds the maximum limit of the ideal temperature	6.875	6.375	4.375	191.75	43.83
15	The accuracy of the scales has not been calibrated so that if there is an indication of problems with the scale as a measuring tool, it affects the sampling of the percentage of defects in shrimp	4.500	4.750	5.375	114.89	21.38
16	Damage to the soaking machine results in limited working capacity in the soaking area, so that the reservoir before soaking accumulates	6.750	5.125	5.375	185.94	34.59
17	Damage to the cooling engine so that the engine speed or temperature is not optimal	7.500	4.875	4.750	173.67	35.56
18	The minimum core temperature in shrimp after freezing is not achieved	6.875	4.375	3.375	101.51	30.08
19	The minimum core temperature in shrimp after hardening is not achieved	6.875	3.750	3.625	93.46	25.78
20	The sealing machine experienced problems so that the sealing process ran slowly causing a buildup of products resulting in a decrease in shrimp temperature	6.875	5.750	3.375	133.42	39.53
21	The temperature in cold storage is not optimal so that the minimum temperature of the standard storage in cold storage is not reached	8.250	6.625	4.125	225.46	54.66
Total		3232.75	796.41			
Critical Value		153.94	37.92			

Evaluation of Potential Hazards or Risk Sources in Blackspot and Blacktail Defects

Risk evaluation or risk measurement using the FMEA method. The RPN and RSV values of each potential hazard or risk source are analyzed using a pareto diagram and then the intersection with the critical values of RPN and RSV is determined to determine the priority of improvement or risk control. Potential hazards or sources of risk that have RPN and RSV values that exceed their critical values are prioritized for improvement recommendations. The critical RPN value is 153.94 and the critical RSV value is 37.92. Of the 21 potential hazards or risk sources of blackspot and blacktail defects, there are 12 potential hazards or risk sources that have an RPN value that exceeds the critical RPN value and 10 potential hazards or risk sources that have an RSV value that exceeds the critical RSV value.

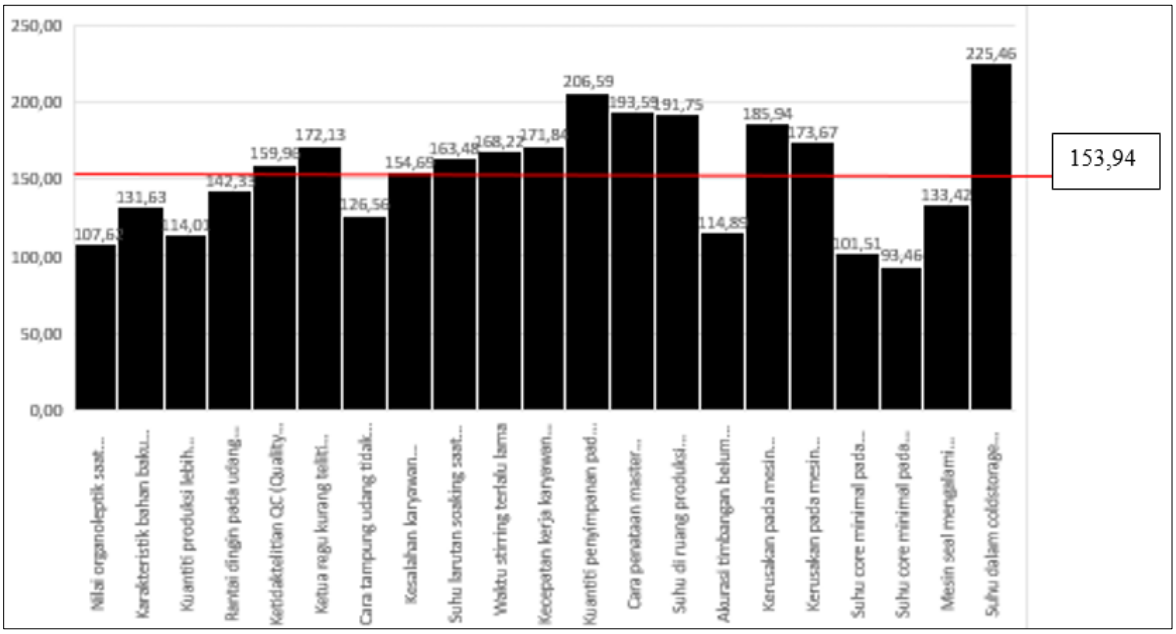

Fig 3: RPN Values of Blacktail and Blackspot Defect Potential Hazard / Risk Sources

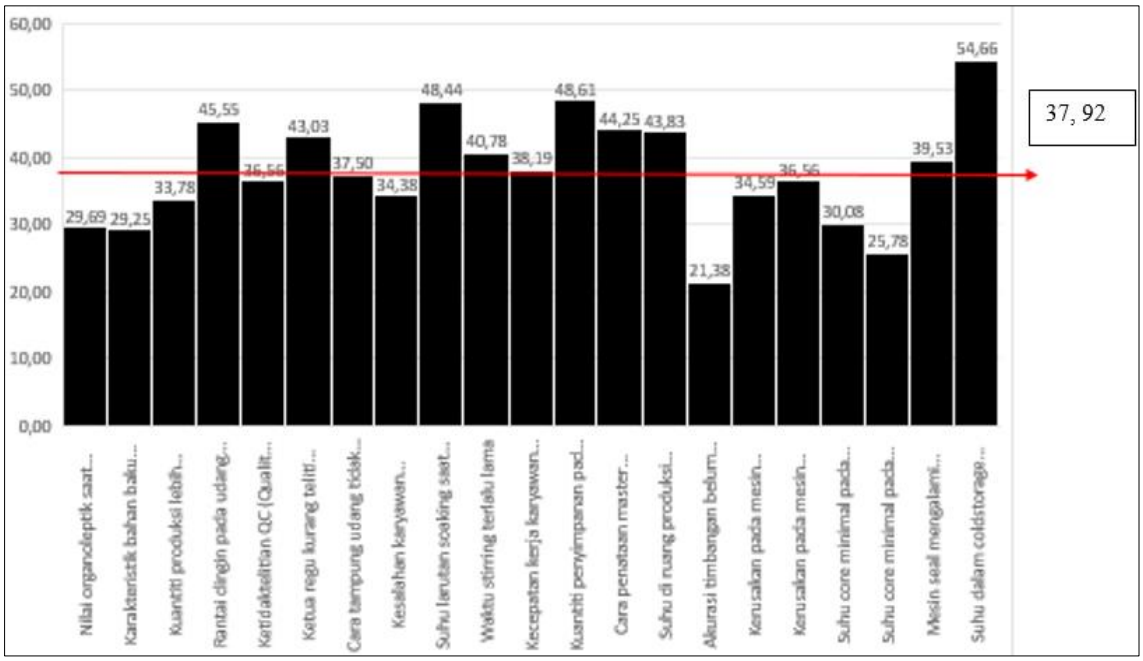

Fig 4: RSV Values of of Blacktail and Blackspot Defect Potential Hazard / Risk Sources

Based on the highest RPN and RSV values, 2 potential hazards or sources of risk of defect blackspots and blacktails are determined which are recommended for repair priorities. The first potential hazard to be a priority recommendation for improvement or risk control is the temperature in coldstrorage is not optimal so that the minimum temperature of the standard storage in cold storage is not reached. The second potential hazard is that the storage quantity in cold storage exceeds the standard limit. Both sources of risk or potential danger, are the cause of the temperature increase in products stored in coldstorage. Meanwhile, the increase in temperature is a potential cause of the occurrence defect blackspot, blacktail and discolour on the product, as described in Yuniarti *et al*., (2018) [11] formation of blackheads (blackspot) on the shrimp body will take place continuously at temperature storage chilling. The formation of these blackheads can be inhibited at freezing temperatures.

The deterioration of shrimp quality is closely related to the appearance of black color found in the shrimp carapace. The color reaction that occurs is the formation of black, which is called blackspot (Haard & Simpson, 2000 as cited in Irsyad, 2020).

Refrigeration or freezing is the traditional method that is used to control bacterial spoilage which helps delay the blackening of shrimp. However, during the period of refrigeration or freezing, the PPO remains active, and the problem of blackening still exists (D. Xu *et al*., 2018 as cited in Wang *et al*., 2022) [10]. Coldstorage is a facility designed to maintain the quality and safety of products by controlling storage temperatures. The minimum temperature standard set by the processing unit at the storage in coldstorage is -21±2°C so that the storage temperature set by BPOM for processed food products is reached (minimum -18°C). If the minimum storage temperature standard is not reached, then frozen

shrimp products (frozen shrimp) stored in coldstorage can experience quality degradation.

It can be concluded that a defect blackspot is a black spot on the head to the body of a shrimp, while a blacktail is a black spot on the tail of a shrimp. Blackspots are caused by an enzyme reaction due to temperature changes or fluctuations. Rising temperatures are one of the causes of the appearance of blackspots and blacktails in shrimp. Product handling in maintaining the cold chain is very important in preventing defects of blackspots and blacktails in shrimp.

Excess quantities of products stored in cold storage cause less air circulation in cold storage so that the cold temperature in cold storage increases. In addition to the increase in temperature, another risk resulting from the excess quantity of products during cold storage is the unevenness of the cold temperature inside, which has the potential for temperature rise at certain points in cold storage higher than others. Therefore, the quality safety of products stored at the points with the highest temperature fluctuations needs to be re-checked.

These blackspot and blacktail defects will potentially affect the economic value of the shrimp because of the influence of consumer or buyer acceptance of shrimp with blacktail and blackspot defects. This defect affects the appearance of the product, shrimp appears to have black parts on the body and tail of the shrimp. Colors other than the natural color of shrimp can certainly be clearly seen by buyers and result in rejection if found in large quantities.

Through the RPN and RSV assessment, it can be concluded that the temperature in cold storage is not optimal so that the minimum temperature of the standard storage in cold storage is not reached and the storage quantity in cold storage exceeds the standard limit is a source of risk or potential hazard priority that will be further analyzed regarding the handling strategy to anticipate the existence of blackspot defects and blacktail in the production process of frozen vannamei shrimp.

Controlling Risk Sources in Blackspot and Blacktail Defects

The last stage of risk analysis after risk identification and risk measurement (risk evaluation) is risk control. Recommendations for corrective actions or risk control as well as preventive measures against potential hazards or sources of risk are determined after being analyzed through cause-and-effect analysis (fishbone diagram). Basically, a causal diagram is used to identify the root causes that may arise from a problem. Once the root of the problem has been identified, then the appropriate actions can be determined to overcome the problem (Estu, 2017 as cited in Azhari, 2019) [1]. Based on the calculation of RPN and RSV values against RPN and RSV critical values, potential hazards or sources of risk of quality degradation in the form of blackspot and blacktail product defects in the frozen vannamei shrimp production process are the sources of risk posed by the risk category of machines or equipment and man or employees.

Risk machine or equipment in the processing of frozen vannamei shrimp due to the temperature in coldstorage Not optimal up to the minimum temperature of the storage standard coldstorage not reached. Handling strategies can be carried out in mitigation and Preventive. Mitigation is the control or reduction of the impact caused by risks while Preventive The nature of avoiding or anticipating risks occurs. To avoid the risk of temperature rise in coldstorage Therefore, it is necessary to monitor the temperature periodically in coldstorage, this is considered an action

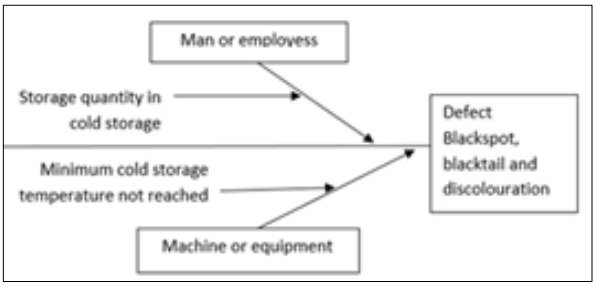

Fig 5: Diagram Fishbone Defect Blackspot dan Blacktail

Preventive that has been carried out by the processing unit to avoid the risk of temperature fluctuations or temperature increases. The purpose of temperature monitoring is if there is an increase in temperature in coldstorage can be identified quickly so that problems can be identified immediately and corrective actions can be taken, as well as efforts to save products can be made immediately. In addition to temperature monitoring, monitoring of machines supporting the production process, including refrigeration machines, is also carried out. Also explained by (Trebar, Lotrič, & Fonda, 2015 as cited in Panjaitan *et al*., 2024) [8], temperature fluctuations during shrimp processing must be controlled to prevent deterioration of shrimp quality. Continuous temperature monitoring along the cold chain system is recommended to maintain temperature management and improve the quality of the final product. Meanwhile, mitigation strategies that can be carried out if temperature rise is identified during the storage period of the product in coldstrage is the rearrangement of products in coldstorage by adjusting the height master carton as well as distance from the wall coldstorage. For internal product monitoring coldstorage, both for preventive and mitigation efforts is the existence of checking treatment Defrost daily by QC line finish products as an effort to monitor the safety and feasibility of products stored in coldstorage.

The risk of man or employee in the processing of frozen vannamei shrimp is caused because the storage quantity in cold storage exceeds the standard limit. Excessive quantities can be anticipated by monitoring the number of goods entering and exiting cold storage and planning balancing calculations between the raw materials to be produced and the number of goods in cold storage and the capacity or capacity of cold storage. The presentation of data on the number and type of products stored in an up-to-date manner in addition to being a form of quantity monitoring can also be used as marketing reference data by marketing. If the stored products can be offered and sold immediately, then a smooth flow of goods in and out will reduce the risk of excessive storage in cold storage. Meanwhile, the strategy or mitigation effort if the quantity in cold storage is excessive is to move the product to another cold storage owned by the processing unit and immediately convey the problem to the management so that marketing can submit a product inspection schedule with the buyer or rearrange the arrival of raw materials according to the capacity of the cold storage.

Potential hazards or sources of risk defect blackspot, blactail and discolouration due to temperature fluctuations, especially temperature during the storage stage. Because of the causes blacktail, blackspot and discoloration in shrimp due to enzyme activity that can be inhibited by cold temperatures. Shrimp that have been frozen at the IQF stage are then coated with ice (Glazing) to maintain a cold temperature after

freezing. If there are temperature fluctuations that result in an increase in temperature, this ice layer or glazing will have the potential to break or melt. Shrimp whose glazing layer has broken or is missing is prone to blacktail, blackspot and discolouration. According to (Liu *et al*., 2024) [6] Penaeus vannamei is susceptible to autolysis and decay during transportation, storage, and sale. In addition, shrimp are also prone to blackening, which reduces consumer acceptance. Shrimp preservation is mainly done through frozen storage, which can inhibit microbial growth, reduce protease activity, and extend shelf life.

Blackspot and Blacktail Defect Data Recap on Product Finish

During the research period from July to September, as supporting data for the research, defect data from the results of checking the finish product was also collected as a material for evaluation and improvement during the production process. Recap defects on product finishes are then used as a reference for defects that are a priority for repair.

Table 6: Recap of Blackspot Defect and Blacktail Product Finish Period July – September

Jenis *Defect*	Jenis Produk dan Total *Defect* per Bulan								
	RPDTO			RPND			RPD		
	Juli	Ags	Sep	Juli	Ags	Sep	Juli	Ags	Sep
Black Spot	0,07	0,04	0,00	0,00	0,00	-	0,00	-	-
Black Tail	0,20	0,14	0,00	0,00	0,00	-	0,00	-	-

Benefits of Risk Analysis on Natural Resource Management

All types of industries, both small-scale industries and large-scale industries, have potential impacts on the environment. In general, the risks to the environment are in terms of the exploitation of natural resources and the risk of pollution to the environment. Industry requires raw materials that are often taken directly from nature. In the frozen vannamei shrimp processing industry, because raw materials are obtained through aquaculture fisheries, there is no threat to the exploitation of natural resources that result in extinction.

A risk other than exploitation from industry is pollution to the environment caused by industrial waste. According to all fish and shrimp processing industries, of course, there is waste that will be discharged into water bodies in the nearest area, one of which is rivers. The shrimp freezing industry generally produces liquid waste that has a high content of parameters such as pH, COD, BOD, TSS, and oil and fat so that it can pollute the river if it is not treated properly before being discharged into water bodies. This not only adds value to industrial processors, but can also have an impact on environmental problems, especially odor problems, which can be detrimental to local residents (Muflida 2014 as cited in Dewangan *et al*., 2022) [2].

With the application of risk management through analysis of the risk of quality degradation, especially related to product defects in the frozen vannamei shrimp processing process, production can run more optimally and effectively. Early identification and control of potential product defects allows the production process to run more efficiently, reduce waste of raw materials, and reduce the rate of product failure. In addition to improving the quality and consistency of the final product, this approach also contributes to the reduction of industrial waste, both in terms of organic waste and process waste can be suppressed thereby reducing the pollution burden and supporting more sustainable and environmentally friendly production practices. Defective products mean that there is a wasted process (washing, freezing and packing), by reducing product defects (product defects) the energy and water used become more economical so as to support resource conservation. Risk analysis helps companies maintain quality without continuously increasing production volumes excessively. This is in line with the principles of sustainable production and good environmental governance.

Overall, although the recapitulation data of blackspot and blacktail defects during the period of July - September is still within safe limits (not exceeding the specification tolerance limit), preventive actions as recommendations for risk control actions need to be implemented with discipline. With the control of potential hazards or sources of risk, it is expected to be able to reduce defects in the product so that the frozen vannamei shrimp production process can run effectively and the utilization of raw materials is more optimal. An effective production process and appropriate product quality can indirectly minimize the negative impacts of shrimp processing industry activities on the environment.

4. Conclusion

Based on the results of the identification of production risks in the processing of frozen vannamei shrimp, it was found that there are 21 types of potential hazards or sources of risk of defect blackspots and blacktails in the production process of frozen vannamei shrimp. Of the 21 potential hazards or sources of risk, they are divided into 3 risk categories, namely the material or environmental risk category, 3 potential hazards or risk sources, the man or employee risk category as many as 10 potential hazards or risk sources and the machinery or equipment risk category as many as 8 potential hazards or risk sources.

Based on the risk evaluation through the FMEA method, it was concluded that there are 10 potential hazards or risk sources for the risk of defect black spots and blacktails that have RPN and RSV values that exceed the critical values of RPN and RSV.

Risk management strategies are divided into 2, namely preventive and mitigation for each potential hazard or source of risk. For preventive risk control measures in the risk category of machines or equipment, temperature monitoring is carried out periodically in cold storage. As for the mitigation risk control strategy, the product rearrangement in cold storage is carried out. For monitoring products in cold storage, both for preventive and mitigation efforts, there is a daily defrost check treatment by QC line finish products as an effort to monitor the safety and feasibility of products stored in cold storage. In the category of human or employee risk, preventive risk control by monitoring the number of goods entering and exiting cold storage and mitigation risk control strategies are to move products to other cold storage and arrange product inspection schedules by buyers or re-receipt of raw material receipts according to the capacity of cold storage.

5. Recommendation

Entrepreneurs, to implement the proposed quality reduction risk control proposal with the aim of anticipating and reducing the risk of failure during the production process. By considering other factors of production such as labor and costs. The proposed treatment strategy depends on the type of defect and the risk category.

Academics, the next research can analyze the effectiveness of the risk management strategies that have been implemented. In addition, it does not analyze in terms of production process risks alone, but can be developed by analyzing failures resulting from other risks such as market risks and financial risks.

The government, in order to provide more facilities or media for socialization and training on product quality, how to process and handle fishery products well, as well as about entrepreneurs so that more people are interested and establish businesses in the field of processing fishery products.

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Authors' Contributions

Dr. Apri Arisandi: Responsible for conceptualizing the research framework, developing the methodology, and supervising the overall study.

Camalia Putriningtyas: Conducted data collection, performed data analysis, and prepared the initial manuscript draft.

Dr. Eko Setiawan : Contributed to the literature review, data interpretation, and revised the manuscript for intellectual content and clarity.

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