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Quality Control of Edamame Products Using Statistical Quality Control (SQC) and Failure Mode Effect Analysis (FMEA) Methods in PT. XYZ

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A B S T R A C T

PT. XYZ is a company engaged in the frozen food processing industry. One such product is Edamame. In the Edamame production process, defects such as pest defects, color defects, pod defects and mechanical defects that affect quality are still found. The purpose of this study was to determine the proportion of defects that most often occur and the factors that cause defects and to provide suggestions for improving the quality of edamame. The methods used are Statistical Quality Control (SQC) and Failure Mode Effect Analysis (FMEA). The SQC tools include check sheets, statistics, histograms, pareto charts, scatter diagrams, control charts, and fishbone diagrams. Then continue the FMEA analysis for suggestions for corrective action. Based on the results of research on Statistical Quality Control (SQC) it is known that the most dominant defects in edamame are pests (39.9%), then color (25.5%), pods (25.2%), and mechanics (9.4%)). Based on the results of research on Failure Mode Effect Analysis (FMEA) it is known that the highest cause of problems with RPN 360 is lack of sanitation. Suggestions for improvement that can be proposed namely. Scheduling cleaning of the work environment area and sterilizing production machines and equipment.

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1. INTRODUCTION

The advancement of technology and the rapidly changing market conditions in the industry demand that companies must be able to satisfy consumers by providing products that meet the standard quality in line with the company's objectives. The operational activities of a company can run effectively and efficiently if the company implements quality control to reduce product failures or damages, aiming to achieve the required quality standards (Meldayanoor et al., 2018).

PT XYZ is a company engaged in the production of frozen food, one of its superior products is edamame. As a quality-oriented company, PT XYZ realizes the importance of quality control to maintain consumer confidence in the products produced. Therefore, in the production process, PT XYZ always tries to provide the best products for business partners both in terms of price and quality. During the manufacturing process, there are still many defects including pest defects, color defects, pod defects and mechanical defects. And of all the defects that have been observed, it is known that defects in the edamame production process have a total defect of 8.3%.

Based on the explanation of the problem above, the purpose of this study is to determine the percentage of defects that most commonly occur in the production process and the factors that cause these defects. In addition, this study also aims to provide proposed actions to improve welding quality. It is hoped that the results of this study can provide input and contribution to the company in analyzing the quality of the final product produced and determining production quality control policies that can produce quality products following the specified standards. Therefore, in accordance with the discussion above, the researcher applies the SQC method to find out the reasons why product defects occur and FMEA analysis to provide suggestions for improvements to the quality control of edamame production at PT XYZ.

2. LITERATURE REVIEW

This chapter discusses the theories that support and play a crucial role in supporting the research implementation. These include theories on Quality, Quality Control, Statistical Quality Control (SQC), and Failure Mode Effect Analysis (FMEA). These theories will serve as the researcher's guide in conducting the study. Literature The word "quality" has multiple definitions, ranging from conventional to more strategic. The conventional definition of quality usually describes the direct characteristics of a product, such as performance, reliability, ease of use, aesthetics, and so on. The strategic definition of quality is that it is something capable of meeting the needs of customers (Rosyidi, 2020). Quality control is one of the techniques that need to be implemented from before the production process begins, during the production process, until the production process ends with the production of the final product. Quality control is carried out to ensure that the products, whether goods or services, meet the desired and planned standards, as well as to improve the quality of products that do not meet the established standards and maintain the desired quality as much as possible (Supriyadi, 2021).

Statistical Quality Control or statistical quality control is an important application of statistical techniques in the manufacturing industry. Typically, the manufacturing industry receives raw materials from vendors. Therefore, it is important to inspect the raw materials before deciding on whether to accept them or not. It is almost impossible to inspect every item of raw material. Thus, a few items (samples) are randomly selected from a large population of raw materials and individually inspected before deciding on whether the entire population is acceptable or meets the standards (Selvamuthu, 2018). Failure Mode and Effect Analysis is a reliability analysis method intended to identify failures that have consequences affecting the system's function within given application limits, thereby enabling priority actions to be determined. FMEA is an important method for quality prevention and reliability assurance. It involves investigating and assessing all causes and effects of all potential failure modes that may occur in a system, during the earliest phases of development (Putri, 2021).

The relationship between failure modes and effect analysis and statistical quality control lies in the fact that failure modes and effect analysis identify critical sources of defects in quality problems by conducting risk assessments, which can determine the priority of failure mode risks. Through this risk assessment, the severity of the effects of a failure mode (severity), the frequency of failures (occurrence), and the control capability used to detect subsequent failure modes (detection) can be determined. Based on the known risk priorities, actions can be developed and formulated to reduce risks, thereby identifying which recommended actions are useful in preventing defects (Dewi, 2019). Edamame is a type of soybean native to
Japan but has been cultivated in Indonesia. It is typically harvested in the green, immature state.

Edamame is a major export commodity of Jember regency. Based on the data on the export volume of food crops, edamame ranks among the top 3 main commodities of food crop exports in Indonesia. However, the volume of raw and frozen edamame exports is 10 times higher than processed edamame products. The benefits of edamame include being a healthy, cholesterol-free snack that reduces the risk of heart disease, the calcium content in edamame helps rebuild the calcium content in edamame helps rebuild bone density and prevents osteoporosis. The isoflavones in edamame can help prevent cancer and delay menopause.

The protein content in edamame can reduce cholesterol levels, and the antioxidant compounds in edamame can strengthen the immune system. Detection (DET) refers to the measurement of the ability to detect or control potential failures that may occur (Rinoza et al., 2021). Detection (D) is an assessment of the likelihood that a tool can detect potential causes of a failure. Detection serves as a preventive measure in the production process and reduces the failure rate in the production process (Alfianto, 2019).In the evaluation of detection ratings, a scale of 1 to 10 is used. A value of 1 indicates a very high reliability in detecting a process failure, approaching 100%. On the other hand, a value of 10 indicates a very low reliability in detecting a process failure, less than 90% (Taufik, 2021).

3. RESEARCH METHOD

In this research, the Statistical Quality Control method and Failure Mode and Effect Analysis are used. The following flow to solve this problem can be seen in Fig. 1.

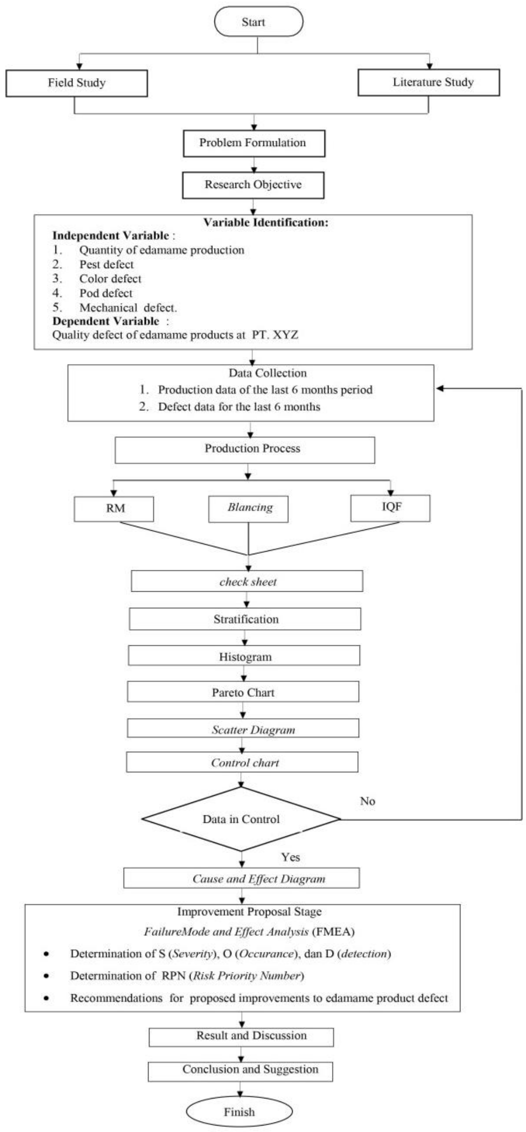

Fig. 1. Research stages

Based on the Fig. 1, the research stages are a series of steps that must be taken in a research process to achieve predetermined goals. The description of the sequence of solving an event above is survey of existing problems to determine the formulation of problems and research objectives, then identify the dependent variable (Quality Defects of edamame products at PT. XYZ) and the independent variable (types of edamame defects). Then collect research data including primary data from interviews with the QC division and secondary data in the form of edamame production data. Next, process the data with the SQC method with a seven tools approach (check sheet, stratification, histogram, pareto diagram, scatter diagram, control chart and cause and effect diagram), then make an improvement suggestion with FMEA analysis based on the calculation of the RPN value of the multiplication of Severity (S), Occurance (O), and Detection (D). These stages form a systematic framework and help researchers to organize and direct the research process clearly and purposefully.

4. RESULT AND DISCUSSION

In the calculation using the SQC method and improvement recommendations using the FMEA method with the following results:

4.1 Check sheet

A Check sheet is a tool used to record the results of data collection for a specific purpose and to present data in a communicative form so that it can be converted into information. The results of data collection on types of defects through check sheets can be seen in Table 1.

Table 1. Check sheet

No	Month	Defect Type			
		Pest	Color	Pod	Mechanical
1	September	26	23	22	7
2	October	15	15	10	5
3	November	5	2	3	1
4	December	25	6	12	6
5	January	16	20	10	3
6	February	27	7	15	5

(Source: Production data PT. XYZ, 2023)

In Table 1. The check sheet data used is the company's internal data or production data of PT XYZ for the last 6 months, where in the check sheet table can record the types of defects that are often found in edamame products, such as pests, color, pods and mechanical. By recording the number of occurrences of each type of defect, it can identify the most common types of defects and focus on appropriate improvements.

4.2 Stratification

Stratification is the stage for grouping data in groups that have the same characteristics. The results of the stratification according to the check sheet are shown in Table 2.

Table 2. Stratification

No	Month	Total Production	Defect Type				**Total**
			Pest	Color	Pod	Mechanical	
1	September	847	26	23	22	7	78
2	October	561	15	15	10	5	45
3	November	142	5	2	3	1	11
4	December	590	25	6	12	6	49
5	January	720	16	20	10	3	49
6	February	580	27	7	15	5	54
	Total	3440	114	73	72	27	286

(Source: Production data PT.XYZ, 2023)

In table 2. Stratification of the data used is the company's internal data or production data of PT XYZ for the last 6 months, where in the stratification table can separate data into subgroups based on certain variables such as, total production in each month, types of defects that are often found, and total defects each month. By using stratification, it can take targeted corrective actions and improve the overall quality of the product or process.

4.3 Histogram

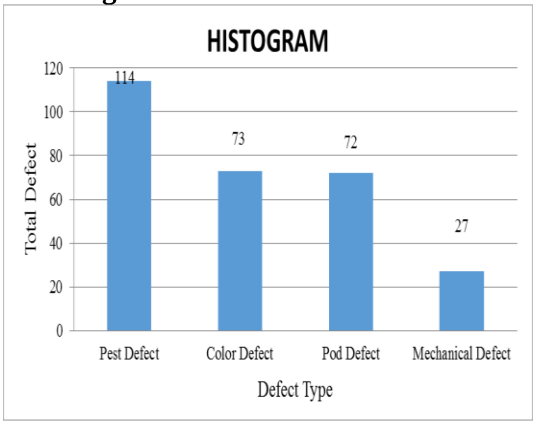

Fig. 2. Histogram
(Source: processed data, 2023)

Based on the histogram figure, it can be seen that the interval order of each type of defect that occurs the most is known to be 114 tons of pest defects, then color defects with a total defect of 73 tons, then pod defects with a total defect of 72 tons and mechanical defects with a total defect of 27 tons.

4.4 Pareto Chart

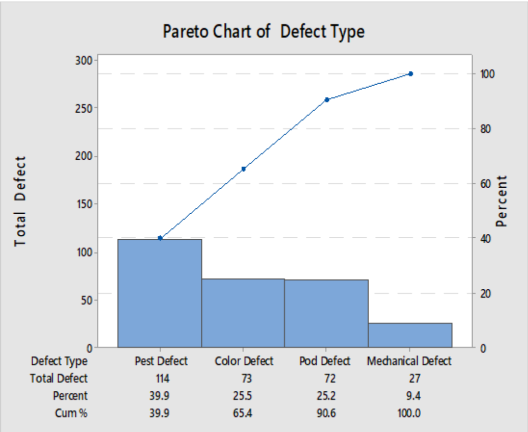

Fig. 3. Pareto chart
(Source: processed data, 2023)

Based on the Pareto diagram, it can be seen that the most dominant type of defect seen from the cumulative percentage is pest defects with a percentage of (39.9%), followed by color defects with a percentage of (25.5%), then pod defects with a percentage of (25.2%), and mechanical defects with a percentage of (9.4%).

4.5 Scatter Diagram

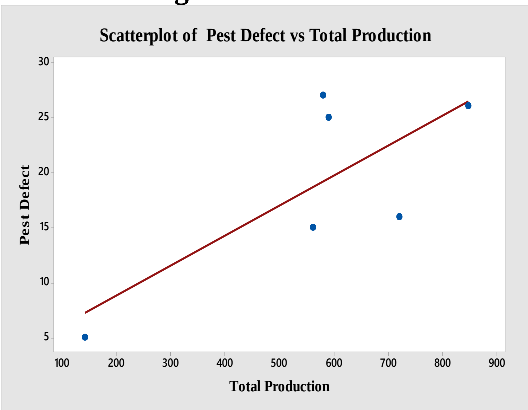

Fig. 4. Scatterplot of pest defect vs total production
(Source: processed data, 2023)

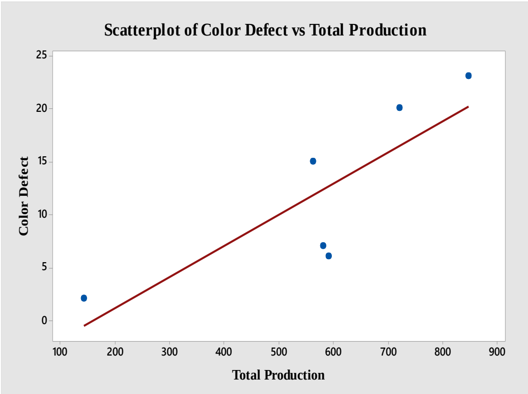

Fig. 5. Scatterplot of color defect vs total production
(Source: processed data, 2023)

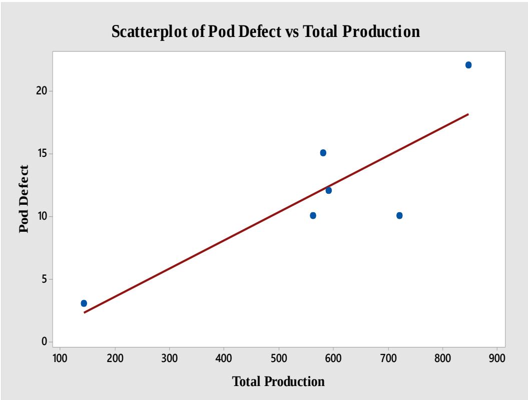

Fig. 6. Scatterplot of pod defect vs total production
(Source: processed data, 2023)

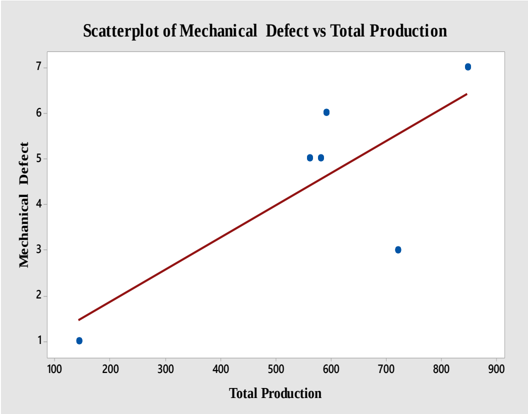

Fig. 7. Scatterplot of mechanical defect vs total production
(Source: processed data, 2023)

Based on the scatter diagram above, the four types of defects, namely pest defects, color defects, pod defects and mechanical defects on edamame production show the results that of the four types of defects where the increasing variable X is followed by an increase in variable Y, meaning that when there is an increase in production, there is an increase in the number of defects as well and vice versa.

4.6 Control Chart

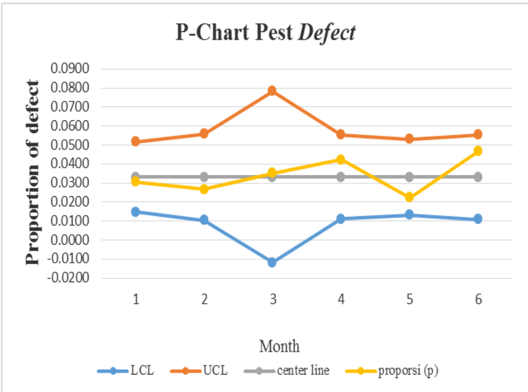

Fig. 8. P-Chart pest defect
(Source: processed data, 2023)

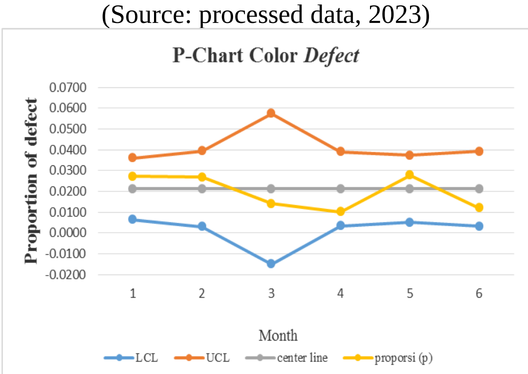

Fig. 9. P-Chart color defect
(Source: processed data, 2023)

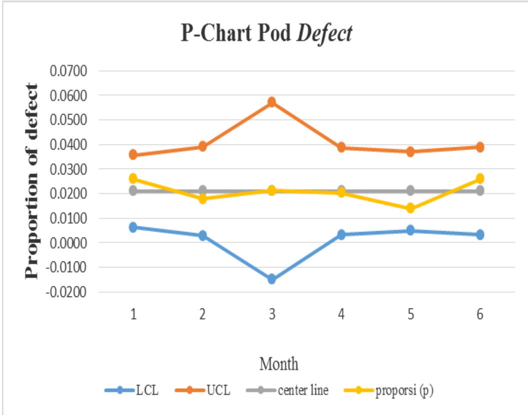

Fig.10. P-Chart pod defect
(Source: processed data, 2023)

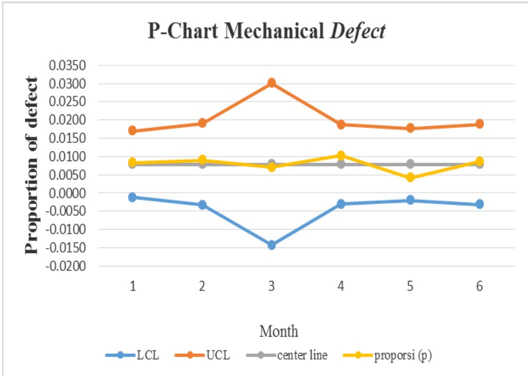

Fig.11. P-Chart mechanical defect
(Source: processed data, 2023)

From the data processing that has been carried out, the data is still within the upper control limit and lower control limit. Since there is no data out of the control limits, it can be concluded that the percentage of defective products in edamame products is within the control limits.

4.7 Cause and Effect

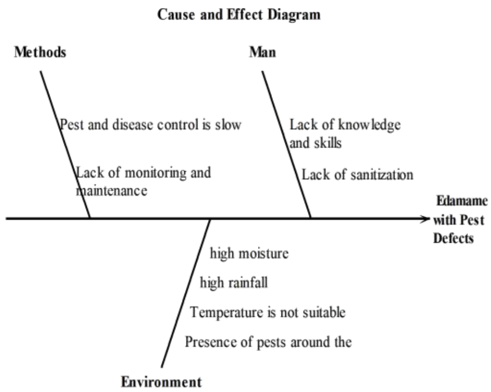

Fig. 12. Cause and effect diagram pest
(Source: processed data, 2023)

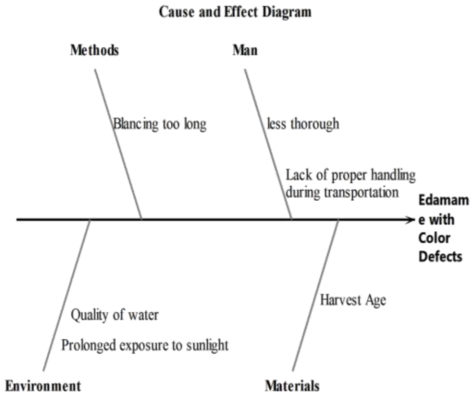

Fig. 13. Cause and effect diagram color
(Source: processed data, 2023)

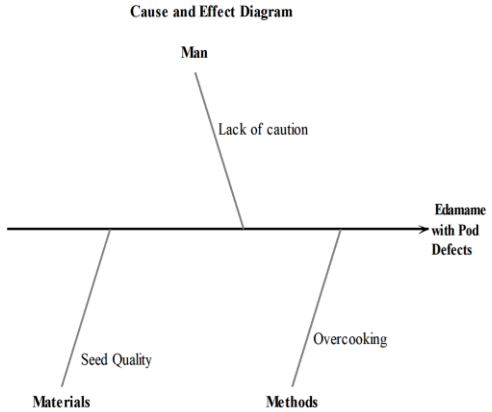

Fig. 14. Cause and effect diagram pod
(Source: processed data, 2023)

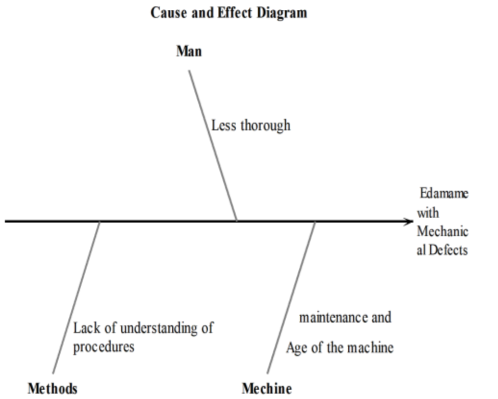

Fig. 15. Cause and effect diagram mechanical
(Source: processed data, 2023)

From Fig. 12-15 the cause and effect diagram above is the root cause of each type of defect in the edamame products studied, namely there are pest defects, color defects, pod defects and mechanical defects. Where the root cause data of the cause and effect diagram is obtained through several sources, namely, first by making direct observations at the company or in the production process by observing the process directly, and identifying the factors that are the root causes of defects. Second, it is obtained from operational data such as production records, inspection reports, and product failure data that provide information about the problems that occur. The third is obtained from qualitative data collection such as interviews with superiors or employees, to gain their insights and perspectives and quantitative data through measurement and statistical analysis provides objective information about variables that affect quality.

Based on the cause and effect diagram, it can be seen the causes of defects in each factor. For pest defects, the cause of the problem is in terms of methods because of slow handling of pests and diseases, lack of monitoring and maintenance, in terms of people because of lack of knowledge and skills, lack of sanitization, and in terms of the environment because of the presence of pests around the work environment, unstable temperature, high rainfall, and high moisture. For color defects, the cause of the problem is from the method because the balancing too long, from humans because lees thorough, and lack of proper handling during transportation, and from the environment because of exposure to sunlight for too long and water quality, from raw materials because of inappropriate harvest age. For pod defects, the cause of the problem is human due to lack of caution, and method due to overcooking, and raw material due to edamame seed quality. For mechanical defects, the cause of the problem is human-caused due to lack of care, and method-caused due to lack of understanding of procedures, machine-caused due to machine age and unscheduled machine maintenance.

4.8 Failure Mode Effect Analysis (FMEA)

Failure Mode and Effect Analysis is a reliability analysis method intended to identify failures, which have the consequence of affecting the functioning of the system within the boundaries of a given application, thus allowing priorities for action to be set (Putri, 2021). Traditionally, FMEA is used to conduct risk analysis through the Risk Priority Number (RPN), which is derived from a combination of Occurrence (O), Severity (S) and Detection (D) (Aprianto et al., 2021.

Table. 3 FMEA frozen edamame

Potential Failure Mode	Potential Effect Of Failure	Potential Cause	Current Control	S	O	D	RPN
Pest	Pest attacks on edamame can reduce the quality of edamame products. Pests can damage edamame pods resulting in physical defects in the product such as perforated and rotten edamame which can affect food safety.	Lack of sanitization	Cleaning and sterilizing production machinery and equipment	9	8	5	360
Color	It will reduce the flavor quality and appearance of the product. Edamame products with color defects can cause a decrease in the visual appeal of edamame products that look less attractive, the quality of taste is not good and is not desired by consumers.	Lack of proper handling when transporting	Provide training to employees or transporters on how to properly handle edamame according to established standards.	6	7	6	252
Pod	Defective pods can lead to a decrease in the overall quality of the edamame product, as defective pods usually have an unpleasant taste and non-ideal texture. If the number of defective pods is large enough, then this can lead to a decrease in the production of edamame products.	Overcooking	Monitor the cooking time more carefully, and adjust the cooking duration so that it is not too long.	7	8	5	280
Mechani-cal	Mechanical defects in the machine can cause damage to edamame and edamame pods, such as cracking or breaking. This can reduce the value of the product and also result in contamination of the edamame product and can even make the product unfit for consumption, hence this can result in food safety risks for consumers**.**	Lack of precision when using the IQF machine	Conduct briefings for workers and adjust the temperature of the production room so that it is not stuffy and disturbs workers' concentration	8	6	6	280

(Source: result focus group discussion with experts, 2023)

Based on the results of the calculation of the RPN (Risk Priority Number) value, it can be seen that the process failures that cause defects, the causes of disability (Potential causes) are then sorted from the highest to the lowest RPN value and then given recommendations for improving each cause. The order of improvement recommendations based on RPN can be seen in Table 4.

Table. 4 Recommendations for improvement based on RPN ranking

Priority	Potential Failure Mode	Potential Cause	RPN	Recommendation
1	Pest	Lack of sanitization	360	Cleaning the work environment and sterilizing production machinery and equipment
2	Pod	*Overcooking*	280	Monitor the cooking time more carefully, and adjust the cooking duration so that it is not too long.
3	Mechanical	Lack of precision when using the IQF machine	280	Conduct briefings for workers and adjust the temperature of the production room so that it is not stuffy and disturbs workers' concentration.

(Source: result focus group discussion with experts, 2023)

Based on the results of the RPN calculation for FMEA edamame products, several risks are obtained that have the highest priority level for making improvements to minimize the possibility of errors. The calculation of the highest RPN value is 360 from the type of pest defect with the potential cause of lack of sanitation with proposed recommendations to clean the work environment and sterilize production machinery and equipment, the second order is the RPN value of 280 from the type of pod defect with the potential cause of overcooking with the proposal to monitor the cooking time more carefully, and adjust the duration of cooking so that it is not too long. The third order is the RPN value of 280 from the type of mechanical defect with the potential cause Workers are less careful when using the IQF machine with the proposal to conduct briefings for workers and adjust the temperature of the production room so that it is not stuffy and disturbs workers' concentration. After taking action for the 3 priority rankings (Pests, pods, Mechanical), where the number of defects has decreased and is under control within the standard defect limit set by the company which is 5%. Previously, of all the defects that have been observed, it is known that defects in the edamame production process have a total defect of 8.3%, which is outside the predetermined standard limit of 5%. The relationship between SQC and FMEA lies in the way they complement each other in solving edamame quality control problems. SQC is used to control quality during the edamame production process, while FMEA is used to identify and address potential failures in the design or production process of edamame. Here is a further explanation of the relationship of each tool in edamame quality control problem solving:

SQC (Statistical Quality Control):

1. Data collection, in the SQC method, data related to edamame quality such as size, number of edamame pods, etc. are collected regularly during the production process.
2. Statistical Analysis, the collected data is analyzed using statistical techniques such as stratification, check sheets, histograms, pareto, scatter diagrams or map diagrams to identify significant patterns, deviations or changes in edamame quality.
3. Action Taking, If the statistical analysis indicates any deviation from the set quality standards, corrective measures such as machine adjustments, process parameter changes, or operator training can be taken to control edamame quality.

FMEA (Failure Mode and Effects Analysis):

1. Identify Potential Failures, in the FMEA method, the team comes together to identify

various failure modes that may occur during the edamame production process, for example, non-standard pod count, pest contamination, color difference and mechanical defects.

2. Effect and Risk Evaluation, once the failure modes are identified, analyzes the potential effects of each of these failures on edamame quality and the impact on customers or consumers. Risk levels are assigned based on a combination of failure severity, occurrence and detection.
3. Corrective Action, after analyzing the risk of failure, proposes and implements appropriate corrective actions to reduce the risk of the failure.

SQC and FMEA complement each other in optimizing the quality control of edamame products. SQC helps in controlling quality during the production process, while FMEA helps in identifying and addressing potential failures through risk analysis and appropriate corrective actions.

5. CONCLUSION

Based on the results of data processing with statistical quality control (SQC), it is known that the highest defect with the Pareto diagram is the most dominant type of defect is pest defect of 114 with a percentage of (39.9%), followed by the color defect of 73 with a percentage of (25.5%), then pod defect of 72 with a percentage of (25.2%), and mechanical defect of 27 with a percentage of (9.4%). Factors causing pest defects are slow handling of pests and diseases, lack of supervision and maintenance, lack of knowledge and skills, lack of sanitation, the presence of pests around the environment, unstable temperature, high rainfall, high humidity. Based on the results of the RPN calculation for FMEA of edamame products, several risks are obtained that have the highest priority level for making improvements to minimize the possibility of errors. The calculation of the highest RPN value is 360 from the type of pest defect with the potential cause of lack of sanitation with proposed recommendations for cleaning the work environment and sterilizing production machinery and equipment.

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