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Extend Product Shelf Life to Minimize Customer Complaints by Using Selected Packaging Materials

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Keywords

8D methodology, customer complaint, product shelf life, packaging material, quality

Abstract

The majority of complaints received by PT XYZ were related to the quality of products not meeting the promised age, particularly regarding the discrepancy between actual and claimed product shelf life on wafer roll packaging. This research employed a descriptive quantitative approach utilizing an 8D methodology integrated with various Quality Management Systems (QMS) tools to identify the root cause of customer complaints. Additionally, the Sorption Isotherm Method was utilized for theoretically accelerated shelf-life testing aimed at designing more efficient packaging solutions. The main goal was to reduce complaints by implementing a tailored Quality Management System. The findings indicated that the existing plastic types (PET12/INK/ADH/VMPET12/ADH/LLDPE 50), with a WVTR value of 0.5 g H2O/m^2. day, were not suitable for wafer roll products with a 15-month product life. Conversely, alternative packaging materials with a permeability value of 0.0032125 g H2O/m^2. day. mmHg and WVTR value ≤ 0.1596 g/m^2/24 hours were identified as capable of achieving the desired product shelf life. This approach significantly reduced customer complaints related to product shelf life by selecting appropriate packaging materials for wafer roll products. Following the implementation of the task force project, complaints decreased from 7 cases to 0 cases of customer complaints regarding soggy wafer roll products at PT XYZ observed within 12 months.

1. Introduction

Good product quality will increase consumer satisfaction with the company. According to Drozd & Wolniak [1], product quality depends on customer requirements since it is subjective. Social demand drives the industry's strategic goal. Quality control is crucial in manufacturing to guarantee that products meet customer specifications, reduce defects, and deliver high-quality products with precise specifications to minimize customer complaints [2]. Improving product quality has both internal and external benefits. Internally, it can lead to better process performance, shorter product delivery times, reduce costs, improve documentation integration systems, and increase awareness of higher quality. Externally, it can result in increased customer satisfaction, enhanced company competitiveness, and a better company image, making it more competitive in the global market [3]. Manufacturing companies need to prioritize maintaining high product quality to satisfy customer demands. By ensuring high product quality, manufacturing companies can enhance their competitiveness, as it enables them to boost their profits. Therefore, the primary objective of manufacturing companies is to uphold the quality level of their products through the application of various management methods [4]. Therefore, food companies use quality

management systems to ensure high-quality products and customer satisfaction and implement continuous improvement processes [5].

Customer complaints can serve as an opportunity for the development of the company's product quality or service. Therefore, the root cause of customer complaints needs to be resolved immediately. Customer complaints often arise from poor customer service or product failure. Researchers may investigate if service failure findings can also apply to product failures [6]. Analyzing customer complaints over time can help identify areas for service improvement and recovery. It is important to note that while reviews can help identify key service features, they are limited to providing static analysis of service quality [7]. This feedback can come in the form of negative feedback, such as complaints and expressions of dissatisfaction, which require corrective actions to address problems. It can also come in the form of positive feedback, such as compliments, expressions of gratitude, and appreciation [8]. Any business must prioritize customer satisfaction to remain competitive and build a strong brand. Addressing customer complaints promptly is vital in preventing potential complications. Additionally, complaints can provide valuable insights into identifying areas of improvement and conducting research and development to create new products or services [9].

Organizations must implement a Quality Management System to meet customer satisfaction requirements for product quality fulfillment. The Quality Management System is a guide for determining the most effective and efficient methods according to the ISO 9001: 2015 standard [10]. According to Budayan & Okudan [11], the Total Quality Management method is a comprehensive system that enables companies to improve their processes from design to delivery, resulting in better performance and customer satisfaction. Manufacturing company managers and practitioners require a problem-solving framework to address quality issues and process problems throughout the product life cycle. This framework must include investigative tools for cross-functional teams that encourage both internal cooperation and external organization. One effective tool is the 8D approach, which investigates the root cause of the problem and provides corrective and preventive actions to prevent recurrence. Other tools that can be used to help improve product quality and ensure sustainable production processes include 5Whys, and Six Sigma [12]. Learning problem-solving skills from a young age is essential. These skills should be developed and improved over time to solve more complex problems. A problem-solving method is chosen based on the complexity of a problem which can impact the effectiveness of the solution. The Total Quality Management method is commonly used in manufacturing industry for problem-solving [15].

The significance of product shelf life is related to product quality and safety factors. Product shelf life must be mentioned on the packaging to preserve product safety and safeguard consumer health [14]. Quality assurance is required during both the production process and the product's shelf life [15]. According to Walsh & Leva [16], the increased product shelf-life and globalization have resulted in longer and more convoluted food chains, potentially offering additional contamination and microbial growth opportunities. Modern food safety management systems analyze hazards (using the latest scientific data) and attempt to control them, which is often complex. However, it also directly influences operational efficiency and the company's long-term performance. Because food is perishable, the duration of travel and storage conditions (e.g., temperature, moisture, packaging) are critical not only for food quality and safety but also for extending shelf life [20].

Packaging material is one of the factors that affect the shelf life of products. This is the foundation for creating the final packing shape. Due to market trends focusing on presenting product innovations to the market, especially those linked to packaging, it is critical to act toward the development of concepts and the creation of packaging material innovations affecting the preservation or extension of the shelf life of products [18]. According to López-Gómez et al. [19], active packaging ensures the optimal release of essential oils, with more initial release (surge effect) in open packaging, potentially extending the shelf life of the product. Researchers have recently created functional, active packaging solutions (active linear low-density polyethylene (LLDPE) film) that may interact with food goods, package headspace, and the environment to extend product shelf life [20].

2. Literature Review

So far, the company had only relied on general problem-solving techniques to overcome customer complaints. Handling customer complaints is a decision-making process that inherently involves a classification problem where each complaint should be classified exclusively into one of the complaint categories before a resolution is communicated to customers [21]. According to Alkan & Harrison [22], we need the study to demonstrate that this approach assists managers in identifying the underlying causes of structural system complexity and the need to provide a systematic approach for comparing alternative system designs during the early phases of system planning. To maintain continued success in an organization, it is essential to identify any areas that require immediate improvement in the quality system. It is crucial to prioritize solutions that raise employee awareness and management attention, as well as provide lean training to eliminate waste across the organization. This solution must be taken seriously [23].

When endeavoring to tackle issues, such as those related to root cause analysis, it is crucial to commence by acknowledging the problem, contemplating potential causes, and subsequently ascertaining which of these

conjectures are pertinent. Keeping a list of known problems in a spreadsheet can help investigators identify the root causes of reoccurring issues [24]. The relationships between complaints and related parameters and processes are analyzed through various statistical methods, and techniques to investigate the root causes so that we can make recommendations for improvements [25]. Thorough investigation and brainstorming are necessary to accurately identify the root cause and prevent problem recurrence during transitions between root cause analysis and quality improvement [26]. According to Guo et al. [27], this approach should prioritize teamwork, quickly identify changing system needs, improve management understanding of the problem and solution, require direct and transparent problem resolution, and effectively prevent similar problems from recurring.

The company has not considered the accelerated shelf-life theory of the product at the initial launch of the product, leading to potential errors in testing the actual shelf life of the product. The pre-production stage requires historical data sets on errors, advanced statistics, and data mining approaches to identify fault patterns and obtain appropriate interpretations for diagnosing natural root causes in physical processes [28]. Using data science activities can be an effective way to improve decision-making and business processes in production environments [29]. The shelf life was estimated using the Accelerated Shelf-Life Test (ASLT) technique and the Arrhenius equation model [30]. The purpose of accelerated stability testing is to evaluate the sort of deterioration that may occur after long-term storage. A product must be subjected to high temperatures and humidity cycles to accelerate deterioration.

Improper selection of the packaging material properties results in the shelf life of the product being less than the shelf life expected by the company. It is critical to emphasize that not only synthetic packaging materials but also biomaterials geared at specific food items require optimum barrier qualities [31]. The exact properties of packaging materials with suitable barriers to moisture, such as thickness, porosity, moisture, and chemical composition, should be carefully considered. The packaging design can provide optimal product protection against moisture and other environmental factors. This can help maintain product quality and extend shelf life, which is crucial in the food industry. Generally, the lower the Water Vapour Permeability and Water Vapour Transmission Rate values of the packaging, the better the packaging protects the product from moisture penetration. The quantity of moisture that travels through a unit of material area per unit of time is referred to as Water Vapour Permeability (WVP). Low numbers suggest that the items will last longer [32]. Water Vapor Permeability (WVP) is an essential feature of films used for food packaging as it directly affects the shelf life and food quality. A lower WVP exhibits superior moisture barrier characteristics, which is critical for maintaining freshness and reducing moisture-related food degradation [33]. According to Eulálio et al. [34] in their research, it is important to analyze the property film for wound dressing materials in terms of qualitative assessment, thickness, Water Vapour Permeability (WVP), Water Vapour Transmission Rate (WVTR), wettability, degradability, cytotoxicity, and good tenseness. Avramia & Amarie [35] stated that the addition of hygroscopic compounds, plasticizers, and surfactants was tested to detect a suitable packing film that included the thickness, WVTR, WVP, film opacity, water activity, moisture content, and color profile. Finally, a statistical relationship was established between dependent and independent factors, such as chemical film composition.

Even though several studies have discussed identifying the root causes of soggy products, there is still a lack of research that specifically investigates the root causes of soggy wafer roll problems using tailored Quality Management Systems (QMS) tools to prevent the recurrence of customer complaints. Several studies have investigated surface moisture accumulation during microwave baking that leads to soggy food products [36]. Research has shown that dry cereals and snacks become less brittle when they absorb moisture, and a partial plasticization process occurs, preventing them from getting soggy [37]. The desired crispy texture cookie (the product that doesn't get soggy) is obtained by changing the formulation of the dry cake mix [38]. The shelf life of plantain chips can be significantly extended by packing them in high-density polyethylene bags, which protect them against moisture transmission [39].

Therefore, the main objective of this study is to investigate the root causes of soggy complaints by applying the 8D methodology enriched with various quality system management tools and quantitative analysis to provide the solutions that are sustainable to prevent the recurrence of these complaints. As a leading publicly traded world-class food manufacturer, PT XYZ is listed in the Singapore Stock Exchange with its affiliated company in Indonesia. This company remains fully committed to ensuring high-quality standards of its manufacturing process, product safety and quality, and consumer welfare. PT XYZ received 13 customer complaints from 2020-2021. Out of 13 cases, 7 cases were related to soggy products. This condition can threaten the company's reputation in the eyes of potential customers and result in more significant losses in the future.

3. Research Methodology

This applied research focuses on applying 8D. The methodology is equipped with various quality management tools to solve problems. The PDCA cycle will help the teamwork to solve the issues due to its method that directly pinpoints and identifies the problem. 8D The methodology consists of 8 steps that must be followed by a task force team consisting of production, maintenance, process control, new product development, quality assurance,

process engineering, and a support team consisting of all managers from all departments who serve as the experts. The team collected the research data through quantitative descriptive approaches using research instruments such as structured observation, trial, and tracking of the production records. The team analyzed the complaint trends by identifying problems systematically to prevent recurrence or reduce the problem significantly as well as for process improvement. The accompanying steps of the 8D methodology can be found in Fig. 1. Here are some tools in the QMS and other analytical tools used in this study as in Table 1.

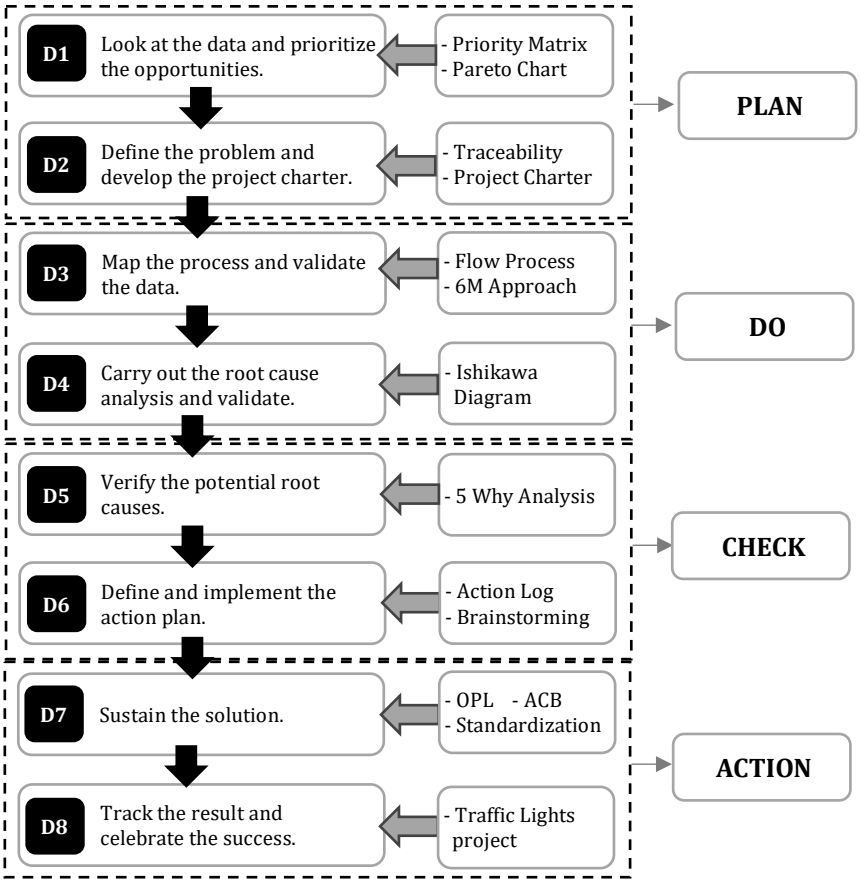

Fig. 1 *8D implementation*

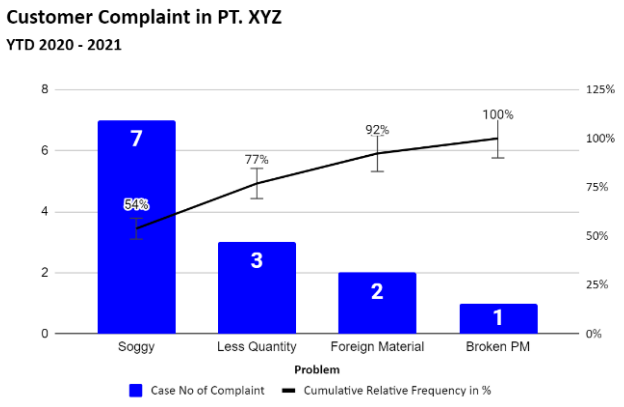

Fig. 2 *Customer complaint data source in PT XYZ*

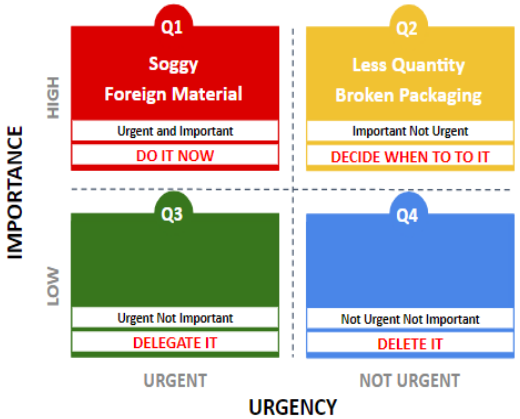

Fig. 3 *Priority matrix customer complaint in PT XYZ*

4. Result and Discussion

The results of the analysis related to customer complaints that need immediate solutions were presented at the routine management review meeting held by the company every month.

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4.1 Look at the Data and Prioritize the Opportunities (D1)

Based on the customer complaint data obtained by PT. XYZ for two years, as shown in Fig. 2, customer complaints of soggy wafer roll products have the highest frequency (7 times in 2 years), compared to other cases. From the case selection process, the management identified four types of customer complaints based on priority matrix criteria, as shown in Fig. 3, and decided to choose customer complaints about soggy products as the project object to be completed first.

4.2 Define The Problem and Develop the Project Charter (D2)

Data tracing related to soggy wafer product complaints was carried out from the process area to the packaging area in production. The observation variables in Table 2 were taken from 7 complaint product records on the production floor.

Table 1 *Quality management system tools*

Tools	Description	References
1. Priority Matrix	Organizations can use the Priority Matrix to classify issues based on their urgency and impact. By prioritizing the issues, organizations can allocate resources more effectively to address the most critical issues first. Typically, this matrix consists of four classifications: Quadrant 1 (High Priority), Quadrant 2 (Medium Priority), Quadrant 3 (Low Priority), Quadrant 4 (Future Consideration).	[40]
2. Pareto Chart	Pareto charts pinpoint crucial business process problems, allowing for focused improvements. They aided in prioritization, helping the teams to determine which issues to address first.	[24]
3. Traceability	The current food traceability system is overly centralized, with major organizations in the supply chain having control and administrative authority over the data. However, by using this system to track food information, it is possible to ensure the safety and dependability of food.	[41]
4. Project Charter	A project charter was created that clearly stated its intention for co-design by deeply engaging key stakeholders throughout the project's life cycle. The research associates expressed their appreciation for the Team Charter as it ensured that everyone stayed on task. Individually, all team members agreed that the project was well-organized, with clear goals, roles, and tasks.	[42]
5. Flow Process	Process Flow is a tool for modeling and improving processes. The project team created a flow process map with internal experts to identify the root cause of the problem.	[43]
6. 6M Method	The 6M method is a framework used in quality and production management to analyze the root causes of problems. 6M represents six key factors that can affect quality, including man, machine, material, method, measurement, and mother nature.	[44]
7. Ishikawa Diagram	Fishbone diagram are helpful tools for conducting a root cause analysis. They assisted in identifying factors that contribute to the issue at hand. The Ishikawa diagram procedure consists of several steps, where the problem is represented in the head of the fish.	[45]
8. 5 Why Analysis	The question "Why?" repeatedly, this method was used to find out the root cause of the problem. A why-why analysis was performed in this study to identify the bottleneck in the process. It is a lean tool that thoroughly investigates each step until no further questions can be asked.	[46]
9. The Sorption Isotherm Method	The sorption isotherm models were utilized to quantify the hygroscopic properties of untreated and modified paper samples.	[47]
10. Action Log Table	Post-brainstorming, several ideas and solutions were generated. Evaluation studies indicated that learners effectively work with these educational instruments, enabling a semi-automated approach to constructive learning.	[48]

11. Standardization	Standardization of procedures is essential in developing the Kaizen system, which can be implemented with certain limitations. These procedures may include technical specifications, standard operating procedures (SOPs), quality guidelines, or specific performance metrics.	[49]
12. OPL (One Point Lesson)	OPLs are popular instructions that are simple documents framed with foil and attached visibly to the machine. They provided information on parameter changes or activities that affected the expected results of the product and the place where the activity was performed.	[50]
13. ACB (Active Communication Board)	The Active Communication Board promotes transparent communication, team collaboration, and proper monitoring of corrective actions. Input was gathered from the ACBS community on the Task Force charge and composition after it was created.	[51]
14. Traffic Lights Project	Project progress was visualized using the traffic light system with green for complete, yellow for in progress, and red for delayed tasks.	[52]

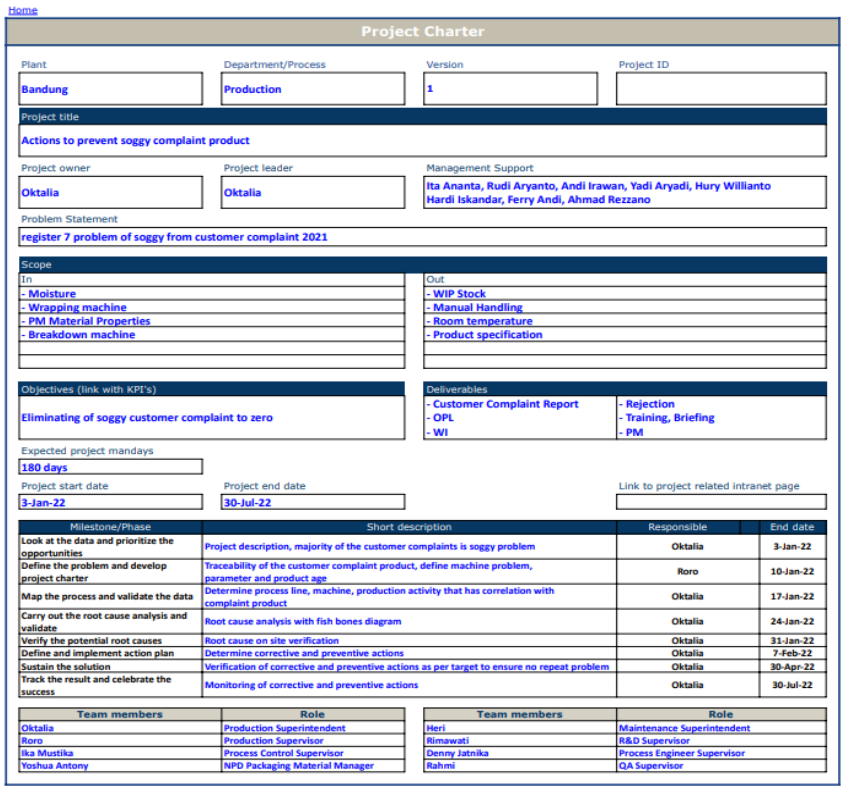
Table 2 *Traceability records of soggy complaints in PT XYZ*

Product No	Product Age	Moisture Content Records of Complaint Products	Actual Moisture Content Retained Samples	Sealing Quality Records	Issue recorded in Wrapping Machines Room	Temperature and RH in Wrapping Room
1	5 months	2.12 %	3.53% - 3.54%	No Issue	No Issue	25^{o}C, 55%
2	4 months	2.97%	3.62% - 3.63%	No Issue	No Issue	25^{o}C, 55%
3	9 months	2.95%	3.29% - 3.40%	No Issue	No Issue	25^{o}C, 55%
4	12 months	2.84%	3.85% - 3.98%	No Issue	No Issue	25^{o}C, 55%
5	14 months	2.83%	3.92% - 3.98%	No Issue	No Issue	25^{o}C, 55%
6	5 months	2.77%	2.75% - 2.86%	No Issue	No Issue	25^{o}C, 55%
7	9 months	2.76%	3.81% - 3.93%	No Issue	No Issue	25^{o}C, 55%

Note: A red mark outside the standard value. Based on wafer roll product specifications, the WIP (work in process) moisture content standard is a maximum of 3% and is stored under an AC room, which has a maximum temperature standard of 25^{o}C and a maximum RH standard of 55%.

It can be identified that the age of the complaint product has not reached the expected product life of 15 months. Based on the production records of the WIP initial moisture content, the data from 7 product complaint samples is within the moisture content standard, which is a maximum of 3% under AC room temperature with a maximum of 25^{o}C and a maximum RH of 55%. Then, as comparison data, the moisture content of product retained samples, which are the same age as the product complaint and stored in the same condition as the production area (maximum temperature is 25^{o}C and a maximum RH of 55%), were taken. The moisture contents of product retained samples have exceeded the maximum standard. The investigation continued with the sealing quality records in the packaging machine. No product quality issues or problems with the packaging machine that could have had any impact on the quality of sealing the product was found. Therefore, further investigation was performed regarding the factors that caused increased humidity, not only in retained sample products but also in product complaints.

The next step is to select and establish a team of people with process knowledge to plan to troubleshoot and determine the prerequisites described in the Project Charter timeline Fig. 4 and monitor the meeting minutes in Fig. 4,



Home

Project Charter

Plant	Department/Process	Version	Project ID
Bandung	Production	1	

Project title

Actions to prevent soggy complaint product

Project owner	Project leader	Management Support
Oktalia	Oktalia	Ita Ananta, Rudi Aryanto, Andi Irawan, Yadi Aryadi, Hury Willianto Hardi Iskandar, Ferry Andi, Ahmad Rezzano

Problem Statement

register 7 problem of soggy from customer complaint 2021

Scope In	Scope Out
- Moisture	- WIP Stock
- Wrapping machine	- Manual Handling
- PM Material Properties	- Room temperature
- Breakdown machine	- Product specification

Objectives (link with KPI's)	Deliverables	
Eliminating of soggy customer complaint to zero	- Customer Complaint Report - OPL - WI	- Rejection - Training, Briefing - PM

Expected project mandays: 180 days

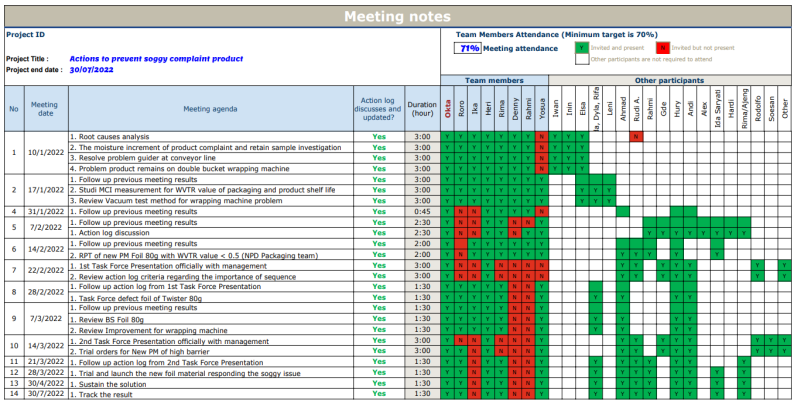
Project start date	Project end date	Link to project related intranet page
3-Jan-22	30-Jul-22	

Milestone/Phase	Short description	Responsible	End date
Look at the data and prioritize the opportunities	Project description, majority of the customer complaints is soggy problem	Oktalia	3-Jan-22
Define the problem and develop project charter	Traceability of the customer complaint product, define machine problem, parameter and product age	Roro	10-Jan-22
Map the process and validate the data	Determine process line, machine, production activity that has correlation with complaint product	Oktalia	17-Jan-22
Carry out the root cause analysis and validate	Root cause analysis with fish bones diagram	Oktalia	24-Jan-22
Verify the potential root causes	Root cause on site verification	Oktalia	31-Jan-22
Define and implement action plan	Determine corrective and preventive actions	Oktalia	7-Feb-22
Sustain the solution	Verification of corrective and preventive actions as per target to ensure no repeat problem	Oktalia	30-Apr-22
Track the result and celebrate the success	Monitoring of corrective and preventive actions	Oktalia	30-Jul-22

Team members	Role	Team members	Role
Oktalia	Production Superintendent	Heri	Maintenance Superintendent
Roro	Production Supervisor	Rimawati	R&D Supervisor
Ika Mustika	Process Control Supervisor	Denny Jatnika	Process Engineer Supervisor
Yoshua Antony	NPD Packaging Material Manager	Rahmi	QA Supervisor

Fig. 4 *Project charter of taskforce 8D implementation for soggy complaints in PT XYZ*

The task force team collected the research data through a qualitative approach using research instruments such as structured interview guides, brainstorming, and analysis of wafer production documentation. This task was performed in six months, from January 3, 2022, to July 30, 2022. Based on the meeting notes in Fig. 5, there were 14 meetings conducted to discuss this project, with the core participants' attendance of 71% (the minimum internal target for core participant attendance is 70%). This shows the commitment to solving this problem.



Meeting notes

Project ID

Project Title : *Actions to prevent soggy complaint product*

Project end date : *30/07/2022*

Team Members Attendance (Minimum target is 70%)

71% Meeting attendance

No	Meeting date	Meeting agenda	Action log discusses and updated?	Duration (hour)	Team members: Oktia	Roro	Ika	Heri	Rima	Denny	Rahmi	Other participants: Yosua	Iren	Elsa	Ita, Dyta, Rifa	Leni	Ahmad	Rudi A.	Rahmi	Gde	Hury	Andi	Alex	Ida Saryati	Hardi	Rima/Ajeng	Rodolfo	Soesan	Other
1	10/1/2022	1. Root causes analysis	Yes	3:00	Y	Y	Y	Y	Y	Y	N	Y	Y	Y				N										
		2. The moisture increment of product complaint and retain sample investigation	Yes	3:00	Y	Y	Y	Y	Y	Y	N	Y	Y	Y														
		3. Resolve problem guider at conveyor line	Yes	3:00	Y	Y	Y	Y	Y	N	N	Y	Y	Y														
		4. Problem product remains on double bucket wrapping machine	Yes	3:00	Y	Y	Y	Y	Y	Y	N	Y	Y	Y														
2	17/1/2022	1. Follow up previous meeting results	Yes	3:00	Y	Y	Y	Y	Y	Y	Y				Y	Y	Y											
		2. Studi MCI measurement for WVTR value of packaging and product shelf life	Yes	3:00	Y	Y	Y	Y	Y	Y	Y				Y	Y	Y											
		3. Review Vacuum test method for wrapping machine problem	Yes	3:00	Y	Y	Y	Y	Y	Y	Y				Y	Y	Y											
4	31/1/2022	1. Follow up previous meeting results	Yes	0:45	Y	N	N	Y	Y	Y	N																	
5	7/2/2022	1. Follow up previous meeting results	Yes	2:30	Y	N	N	Y	Y	N	N	Y																
		1. Action log discussion	Yes	2:30	Y	N	N	Y	Y	N	Y	Y							Y	Y	Y	Y	Y	Y	Y			
6	14/2/2022	1. Follow up previous meeting results	Yes	2:00	Y		Y	Y	Y	Y	Y	Y																
		2. RPT of new PM Foil 80g with WVTR value < 0.5 (NPD Packaging team)	Yes	2:00	Y	N	Y	Y	Y	Y	Y	Y							Y	Y	Y		Y		Y			
7	22/2/2022	1. 1st Task Force Presentation officially with management	Yes	3:00	Y	N	N	Y	N	N	N	N							Y	Y		Y	Y	Y			Y		L
		2. Review action log criteria regarding the importance of sequence	Yes	3:00	Y	N	N	Y	N	N	N	N							Y	Y		Y	Y	Y			Y		Y
8	28/2/2022	1. Follow up action log from 1st Task Force Presentation	Yes	1:30	Y	Y	Y	Y	Y	N	N	Y																	
		1. Task Force defect foil of Twister 80g	Yes	1:30	Y	Y	Y	Y	Y	N	N	Y				Y			Y				Y	Y					
9	7/3/2022	1. Follow up previous meeting results	Yes	1:30	Y	Y	Y	Y	Y	Y	N	Y																	
		1. Review B5 Foil 80g	Yes	1:30	Y	Y	Y	Y	Y	N	N	Y				Y			Y				Y	Y					
		2. Review Improvement for wrapping machine	Yes	1:30	Y	Y	Y	Y	N	N	N	Y				N			Y				Y	Y					
10	14/3/2022	1. 2nd Task Force Presentation officially with management	Yes	3:00	Y	N	N	Y	N	N	N	Y							Y	Y		Y	Y	Y			Y	Y	Y
		2. Trial orders for New PM of high barrier	Yes	3:00	Y	Y	N	Y	N	N	N	Y							Y	Y		Y	Y	Y			Y	Y	Y
11	21/3/2022	1. Follow up action log from 2nd Task Force Presentation	Yes	1:30	Y	Y	N	Y	Y	N	N	Y				Y			Y	Y		Y	Y				Y		
12	28/3/2022	1. Trial and launch the new foil material responding the soggy issue	Yes	1:30	Y	Y	N	Y	Y	N	N	Y				Y			Y	Y		Y	Y		Y		Y		
13	30/4/2022	1. Sustain the solution	Yes	1:30	Y	Y	N	Y	Y	N	N	Y				Y			Y	Y		Y	Y		Y		Y		
14	30/7/2022	1. Track the result	Yes	1:30	Y	Y	N	Y	Y	N	N	Y				Y			Y	Y		Y	Y		Y		Y		

Fig. 5 *Meeting notes taskforce 8D implementation for soggy complaints in PT XYZ*

4.3 Map The Process and Validate the Data (Measurement) (D3)

At the core meeting, the team members brainstormed using the 6M method. At each step of the process, all input processes were recorded using a systematic process flow guide (Fig. 6). All factors that have critical effects on product quality (the cause of soggy products) were identified. These include the quality attributes, all standard ranges from minimum to maximum, and the tools or records used to obtain the data. These factors were needed by the team to identify patterns of findings that lead to the causes of the product soggy problem. The organization of this data can be seen in Table 3 to show the details of each process step. Based on the experiment data, it was found that process steps no. 5, Moisture (the actual moisture content retained samples are out of maximum target)

and no. 7, Wrapping (product shelf life is less than expected shelf life) requires further investigation to identify patterns of findings that point to the source of the problem causing product quality deterioration.

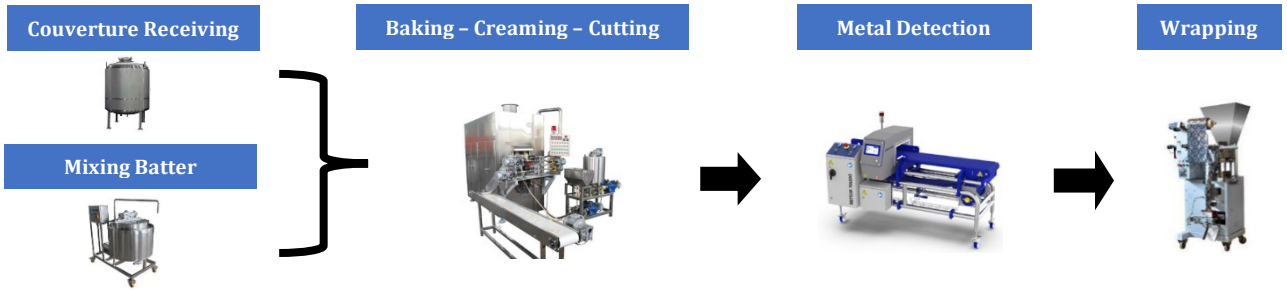


Fig. 6 *Flow process of wafer rolls production*

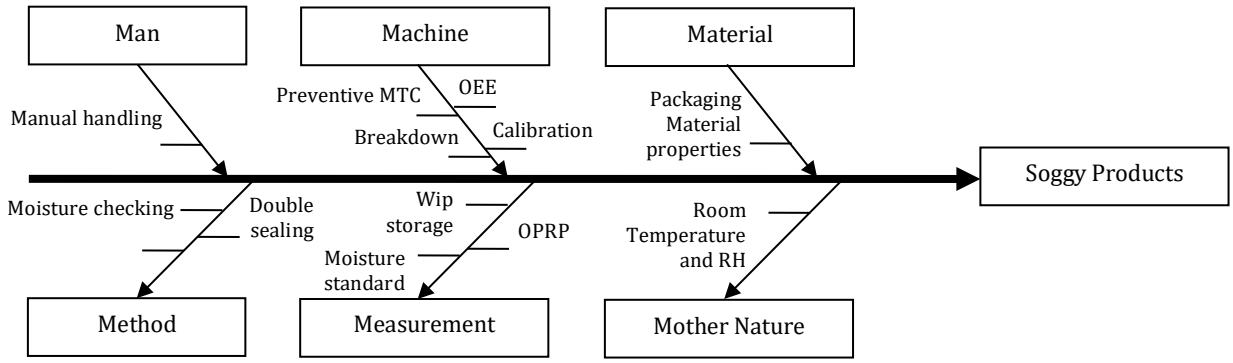


Fig. 7 *Fishbone diagram identifying soggy problem*

Table 3 *Mapping of the flow process of wafer rolls production*

Process Steps (Critical to Quality)	6M Method (Related to Process Input)	Quality Attributes	Numerical Actual Value	Tools
1. RM Preparation	Man	Formula Standard	Within the target of formula correction factor max. 5%	Formulation
	Measurement	Calibrated Weigher	Within the target of weigher correction factor max. 10%	Calibration certificate
2. Batter	Machine	Mixing time	Within the target of Batter Viscosity max. 5%	Mixer batter display
	Measurement	Calibrated Viscometer	Within the target of error correction factor max. 10%	Calibration certificate
3. Cream	Machine	Water jacketing storage tank temperature	Within the target of range temperature max. 5°C	The storage tank temperature display
4. Baking	Machine	Action Criteria (temperature and baking time)	Comply with the OPRP monitoring plan (Temperature min. 110°C, Baking time min. 50 sec.)	Rotating alarm oven records
5. Moisture	Measurement	Moisture Content	Closed to the maximum target moisture content is 3%	WIP moisture records

	Machine	Calibrated Moisture Analyzer	Within the target of error correction factor max. 10%	Calibration certificate
6. Metal Detection	Machine	Calibrated Metal Detector	Within the target of error correction factor max. 10%	Calibration certificate
7. Wrapping	Machine	Product shelf life	Product shelf life is less than the expected shelf life	Certificate of acceptance packaging materials
	Material	OEE	Wrapping machine OEE is less than 85%	OEE records
8. Transfer FG	Machine	Temperature and RH of inventory room	Temperature and RH wrapping room are within the target	Control Records
	Material	Calibrated Thermohygrometer	Within the target of error correction factor max. 10%	Calibration certificate

4.4 Carry Out the Root Cause Analysis and Validate (D4)

After obtaining the production data regarding the potential causes of soggy products, all potential causes of the problem were mapped into a fishbone diagram (Fig. 7) that immediately sorted ideas into useful categories.

4.5 Verify The Potential Root Causes (D5)

From the problem description, all possible causes at the level of why 1 (the main cause) were identified. For each cause (why 1), identify the next cause immediately (why 2) and proceed to the point where we can verify if the cause exists (NOT OK) or does not exist (OK). For an existing cause (NOT OK) to continue to the point where no cause can be identified, then this is the source of the cause. Once the root cause of the problem is obtained using a fishbone diagram, all causes are verified and substantiated in the loop using the five why diagram (Fig. 8) to map the cause against the effect or problem identified as the final cause which is the source of the cause. From this step, a temporary and permanent corrective action plan can be developed. From the results of on-site verification to production, it was found that the main cause of customer complaint products is soggy products due to weak material properties used for product packaging, leading to an increase in product moisture on the market. As a result, the product becomes damaged faster and soggy before the expected shelf life.

4.5.1 Product Shelf-Life Estimation Using the Existing Packaging Materials

a. Determination of initial, critical, and equilibrium moisture content

To calculate moisture content, the sample's known weight was dried at 105°C using an Oven Memmert UFB until a constant weight was achieved. The initial moisture content was measured after draining the wafer rolls. The critical moisture content of wafer rolls refers to the moisture content at which the practicability of wafer rolls is rejected by panelists through organoleptic testing. The equilibrium moisture content was determined using the standard gravimetric method by exposing the wafer rolls to a constant RH environment. At room temperature (27°C), this condition is caused by a saturated solution of a specific salt. To maintain different levels of water activity (aw) ranging from 0.42 to 0.716, five different salts were used in individual desiccators. These salts include Magnesium Chloride, Potassium Carbonate, Sodium Nitrite, Sodium Chloride, and Potassium Nitrate

ROOT CAUSE ANALYSIS	Site/Line : Oven-Wrapping				Product : 80 gram					
Project Title	Why 1	Verified	Why 2	Verified	Why 3	Verified	Why 4	Verified	Why 5	Verified
Problem description (1): Damaged product quality before the expected product shelf life (complaint products)	Product texture evaluation based on the actual shelf life report is under expected shelf life	NOT OK	The product moisture content in the market tends to increase and it was out of the maximum standard	NOT OK	The product moisture content increases due to the absorption of moisture from the environment that can penetrate the packaging	NOT OK	Material properties of packaging have a fair moisture barrier.	NOT OK		
Team Member: Oktalia, Yoshua										
Problem description (2): Soggy product because the WIP itself has already been soggy	WIP stored in the wrapping area has been out of maximum standard moisture	NOT OK	WIP moisture increases due to conveying from the Oven to the Wrapping area	NOT OK	WIP from Oven already has higher moisture close to maximum standard moisture	NOT OK	Specification of product moisture standard need to be reviewed	NOT OK		
Team Member: Oktalia, Roro, Ika, Heri, Mega										
Problem description (3): Soggy product due to leakage sealing	Leak product can be wrapped as finished products.	NOT OK	inaccuracy in the method of sorting defect products	NOT OK	Wrapping Machine Problem (breakdown)	NOT OK				
Team Member: Oktalia, Roro, Heri, Mega										

Fig. 8 *Five why diagrams identifying soggy problem*

b. Determination of Permeability and Water vapor transmission Rate (WVTR)

In this study, existing plastic types were used, namely PET12/INK/ADH/VMPET12/ADH/LLDPE 50. The WVTR value of plastic packaging stated on the Certificate of Acceptance (COA) received from the packaging supplier is 0.5 g H2O/m^2.day.

c. Determination of Product Shelf Life

The Labuza equation (eq. 1) was employed to determine the shelf life of wafer rolls based on the critical moisture content approach. The equilibrium moisture content (Me) was calculated at ambient temperature and RH using the MSI model, which provided the lowest MRD.

$$t = \frac{\ln\left[\frac{Me - Mi}{Me - Mc}\right]}{\frac{k}{x}\frac{A}{Ws}\frac{Po}{b}} \quad (1)$$

Where:

t : shelf life (days)
Me : equilibrium moisture content (g H2O/g dry solid)
Mi : initial moisture content of product (g H2O/g dry solid)
Mc : critical moisture content (g H2O/g dry solid)
k/x : permeability of package (g moisture/m^2.day mmHg)
A : surface area of package (m^2)
Ws : product weight in package (g)
Po : pure water vapor pressure at experimental temperature (mmHg)
b : slope of MSI curve in storage operational area

d. Data Analysis Of Existing Packaging (PET12/INK/ADH/VMPET12/ADH/LLDPE 50)

1. Product weight on a wet basis (Wi) : 80 gram
2. Critical moisture content (Mc) : 0.032 g/g solid
3. Surface area of packaging (two sides, A) : 0.067 m^2
4. Moisture content in wet basis (Mo) : 0.018 g/g wb
5. WVTR at 38 C, RH 90% : 0.5 g H2O/m^2.day
6. Initial Moisture Content (Mo) : 0.019 g/g solid
7. Initial solid weight (Ws) : 78.54 gram
8. Pure Water Vapor Pressure (Po) at 100% RH
   - At 28 °C (Storage Temperature) : 28.349 mmHg
   - At 38 °C (VWTR test) : 49.692 mmHg
   - At 27 °C (MSI test) : 28.739 mmHg
9. Permeability (k/x) : 0.011 g H2O/m^2.day.mmHg

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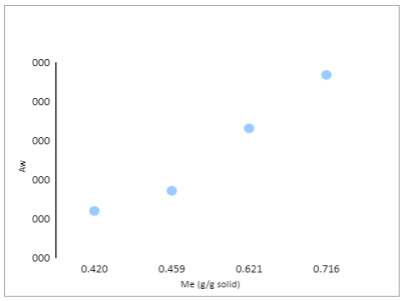
10. Linear curve of MSI :



Slope (b)	Intercept	R2
0.283	- 0.088	0.994

Saturated Salt Solution	Aw	Me (g/g solid)
MgCl2	0.420	0.030
K2CO3	0.459	0.043
NaNO2	0.621	0.083
NaCl	0.716	0.117

Fig. 9 *The linear curve results of MSI for the existing packaging*

11. Me at 80% (Me, g H2O/g solid) : 0.138
12. Product shelf-life at RH 80% and 28°C : 129.306 days (4.3 months)
(LN (Me – Mi)/(Me – Mc))/((A/Ws)*(Po/b)) : 1.446

e. Packaging Material Recommendation

Expected Shelf Life : 15 months.
Permeability (k/x) : 0.0032125 g H2O/m².day.mmHg
WVTR (g H2O/m².day) :

Table 4 *WVTR value for recommended packaging material*

ASTM F 1249 – 90 Condition	100% RH	90% RH
30°C	0.1022	0.0920
30°C	0.1596	0.1437

4.6 Define and Implement the Action Plan (D6)

Selecting and verifying permanent corrections for problems/nonconformities, through preproduction programs, and quantitatively confirming that selected corrections resolved the issues. This is shown in Table 5,

Table 5 *Action log soggy problem*

Priority	No	Issue	Raised By	Action	PIC	Due Date	Status
1 (High)	1	The existing PM had a fair moisture barrier	Ita	Changed PM with high barrier material properties	Yoshua	March 30, 2022	Done
2 (Medium)	2	Wrapping machine breakdown	Hury	Inviting the original supplier to improve the machine's performance	Rezzano	April 30, 2022	Done
3 (Low)	3	Wip moisture increment	Yadi	Set new standard of Wip moisture content in the baking step	Oktalia	Dec 30, 2022	Done

4.7 Sustain The Solution (D7)

Modify management, operations, practices, and procedures to prevent recurrence by using the following steps:

1. Creating COC (Certificate of Conformance) for Packaging Material specification to ensure its WVTR value complies with our requirements as declared in Fig. 10 below.
2. Creating OPL (One Point Lesson) as the visual management (see Fig. 11) to describe the updated Work Instructions for operating the wrapping machine and to standardize all parameters to operate the wrapping machine is suitable with the packaging material type in generating the finished product aligned to the quality standard.
3. Monitoring all procedures, problems, and abnormalities that occur on the production floor regularly and seeking the opportunity to make continuous problem-solving improvements by daily review using the Active Communication Board platform.
4. Determining a lower standard water content of 2% through further research in the Oven Process.

No.	Test Parameter	Unit		Spec.	Result Min.	Result Max.	Remarks
1	Thickness	micron		79 ± 10%	79.4	80.6	
2	Bonding Strength	g/mm	1st Lami.	> 70	263	468	
			2nd Lami.	> 250	378	416	
			3rd Lami.		N/A		
3	Sealing Strength	g/mm	@ 110°C	> 500	2422	3347	
4	Hot Tack	mm	@ 110°C	< 5.0	2.0	2.0	
5	W.V.T.R. *	g/m²/24hrs		< 0.27		0.1474	
6	02 T.R	cc/m/24hrs		< 0.50		0.2854	
7	Solvent Retention *	mg/m²		< 20.0		0.72	
8	C.O.F	In/ In	SA	< 0.35	0.238	0.241	
			KA	< 0.25	0.195	0.210	
		Out/Out	SA	< 0.50	0.375	0.379	
			KA	< 0.40	0.304	0.315	
9	Dimension: Width	mm	± 1 mm	355	355	355	

Fig. 10 *COC of wafer rolls packaging material*

Fig. 11 *OPL for machine wrapping*

4.8 Track the Result and Celebrate the Success (D8)

Congratulate your team and recognize the team's collective efforts in completing the project timeline and the success of the project task force shown in Fig. 12 after the implementation of the 8D method. There was a decrease in the number of customer complaints about soggy products. To maintain the success of this project, it is necessary to monitor the achievements of the Traffic Light Project organization (Fig. 13) and discuss at meetings related to food safety regularly.

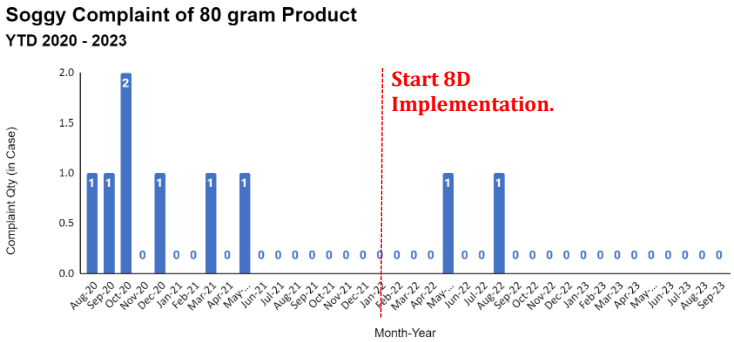


Fig. 12 *Soggy complaints trend PT XYZ in 2020-2023*

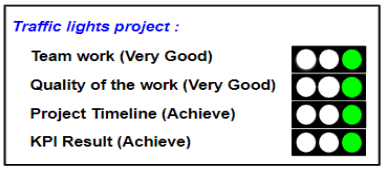


Fig. 13 *Traffic lights project taskforce*

Wafer rolls are delicious snacks made by layering wafer sheets and cream filling and then coating them with chocolate. The wafer is a thin and crispy bakery product made from a fluid batter and baked between hot metal plates with low moisture [53]. However, during storage, moisture can affect their quality, particularly their mechanical properties. Moisture can migrate from the cream or chocolate, and it can also be absorbed from the air [54]. A product's shelf stability depends on several parameters, including gas composition (oxygen and ethylene), pressure, mechanical stress, relative humidity (RH), light, and temperature. Proper storage and handling of products also depend on their packaging and conditions [55]. Wafer rolls require effective packaging to preserve freshness and extend shelf life. The shelf life of a product is crucial for consumer preferences and quality retention. The product shelf-life can be calculated for a specific packaging material or by determining the required barrier property and requesting the packaging solution with that property value from suppliers [56]. Permeability of the package refers to the amount of water vapor that can pass through it per day under certain atmospheric conditions. At certain atmospheric conditions, a package can allow the passage of one unit of the material area per day. Water vapor permeability (WVP) measures the amount of moisture that goes through the material area per unit of time [32]. Based on the results of the analysis, it is known that the packaging type of PET12/INK/ADH/VMPET12/ADH/LLDPE 50 has a permeability of 0.011 g H2O/m².day.mmHgs with WVTR value ≤ 0.5 g/m²/24 hours. This existing packaging has increased WVTR values, indicating greater permeability and lower ability to keep moisture content. The higher the product's moisture, the product will quickly deteriorate in quality and become soggy. The more permeable the packaging is, the more moisture can enter it, which, in turn, shortens the product's shelf life. To prevent water vapor from entering the product, it is necessary to use packaging with low vapor permeability. Therefore, it is essential to use new packaging with a lower WVTR value to reduce permeability and improve its ability to retain moisture content. By using MSI calculations, a material packaging recommendation with a permeability value of 0.0032125 g H2O/m².day.mmHg with WVTR value ≤

0.1596 g/m²/24 hours to get the shelf life of 15 months wafer roll products. There are two types of recommended packaging used in PT DF to replace the existing materials, and those are PET/HBVMPET12/LLDPE 40 and PET/HBVMPET12/LLDPE 50.

In conclusion, the strength of the packaging cannot be overstated in terms of preserving freshness and extending the shelf life of wafer rolls. With suitable packaging materials and smart packaging decisions early on in new product planning and development, manufacturers can ensure their products stay fresh and attract consumers for a longer time. This includes checking the characteristics of the packaging material to identify the material that can best maintain the freshness of the wafer rolls. This led to the identification of smart packaging decisions as a critical factor in extending the shelf life of wafer rolls. With advances in technology, packaging materials can now be re-designed to respond to environmental changes. This capability allows the identification of potential spoilage factors and the ability to take corrective action to maintain product quality. In addition, the use of quality packaging materials is also emphasized in maximizing the life of wafer rolls. The material used must be able to protect the product from outside factors such as humidity, light, and air. It is essential to design packaging in a way that can prevent any physical damage during transportation and storage.

Overall, the selection of comprehensive problem-solving techniques such as 8D methodology equipped with 13 additional quality management system tools (priority matrix, Pareto chart, traceability, project charter, flow process, 6M Method, Ishikawa diagram, 5 Why analysis, Action Log and Brainstorming, standardization, OPL, ACB, Traffic Lights Project) have provided explanatory hypotheses and evaluated the root causes based on the strength of the available evidence. Various conclusions and solutions were derived to ensure the sustainability of the action log in answering the root cause of customer complaints of soggy products on the production floor. After six months of the implementation of this Taskforce Project, there has been a decrease in customer complaints from 7 cases to 0 cases. The leading root cause of the problem has been identified, and reduced. In addition, the problem is less likely to recur after implementing the 8D solving method.

5. Conclusion

The findings in this study are crucial in providing a comprehensive understanding of how quality management system tools can be implemented in global continuous improvement programs. It also provides insights into how these tools can be utilized in the manufacturing industry to address the root causes of customer complaints on the production floor. Standard methods used previously for problem-solving, such as nominal group techniques, multi-voting, and simple voting to decide which ones to investigate first, are less effective in making corrective action decisions and the problems recur without a recognizable reason. The application of various quality management system methods and quality leadership techniques is used to ensure the task force project runs according to the established timeline. In this study, it is found that the packaging standards are not suitable for obtaining a predetermined product shelf life of 15 months. This is proven by the actual calculation of product shelf life and accelerated shelf life of products using existing packaging, where the product shelf life is less than expected shelf life. Corrective action by changing the type of packaging suitable for the expected shelf life of 15 months has proven to be an effective solution to the problem at hand. This corrective action has reduced the number of customer complaints about soggy products. From January 2022 to December 2022, there was a decrease in customer complaints from 7 cases to 0 cases within 12 months. This research has a weakness in that it has not conducted further analysis of other causes of customer complaints related to soggy products, namely the relationship between the increase in moisture content and product quality. Future research can examine these causes to eliminate customer complaints of soggy products effectively.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm their contribution to the paper as follows: ***study conception and design:*** *Oktalia Rusman, Iphov Kumala Sriwarna, Yudha Prambudia;* ***data collection:*** *Oktalia Rusman;* ***analysis and interpretation of results:*** *Oktalia Rusman;* ***draft manuscript preparation:*** *Oktalia Rusman, Iphov Kumala Sriwarna, Yudha Prambudia. All authors reviewed the results and approved the final version of the manuscript.*

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