INTERNATIONAL JOURNAL OF INDUSTRIAL MANAGEMENT (IJIM)
ISSN: 2289-9286 e-ISSN: 0127-564X
VOL. 14, ISSUE 1, 557 – 579
DOI: https://doi.org/10.15282/ijim.14.1.2022.7598

ORIGINAL ARTICLE

IMPROVE PRODUCT QUALITY AND PRODUCTION PROCESS WITH INTEGRATION OF SIX SIGMA AND QUALITY MANAGEMENT SYSTEM ISO 9001: A CASE STUDY OF BAKERY SHOP IN FRANCE

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ABSTRACT – This study highlights macarons product research conducted in a bakery shop in France. It is aims to optimize the quality of the macarons products via the integration of Six Sigma and Quality Management System, ISO 9001. To achieve the objective, the study first identifies the primary root cause of product defects. Besides, an alternative standard operating procedure is incorporated with the recommended improvements. The DMAIC approach is emphasized by the Six Sigma approach, which is Define-Measure-Analyze-Improve-Control. According to the data, the cost of poor quality for a month is 34,511.40 Euro. Cracked macarons (53.70%), hollow macarons (16.30%), and no feet macarons (16.10%) are three major critical defects. The macarons product has a Sigma level of 2.50. The parameters proposed in this study are low-level mixing at 80 rpm, 12 minutes of baking time, and 203°c oven temperature to improve the quality of macarons product using the Design of Experiment (DOE) of the Taguchi Method. When the major elements are controlled inside the processes, the company's chances of producing a high-quality product increase significantly. As a result of adopting Six Sigma with Quality Management System ISO 9001 into the macaron manufacturing process, defects costs and rate is expected to be lower.

ARTICLE HISTORY
Received: 6-4-2022
Revised: 11-4-2022
Accepted: 20-7-2022

KEYWORDS
Product Quality
Six Sigma
QMS ISO 9001
Food Industry
DMAIC
DOE of Taguchi Method

BACKGROUND OF STUDY

The newly discovered human coronavirus disease COVID-19 is the fifth known pandemic since the 1918 flu outbreak. In late December 2019, COVID-19 was initially found in Wuhan, China, and has expanded worldwide. The International Committee on Taxonomy of Viruses officially named the coronavirus as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). SARS-CoV-2 is thought to be a carryover of an animal coronavirus that later expanded the potential to transmit from person to person. The World Health Organization (WHO) officially declared the COVID-19 outbreak a global pandemic on March 11, 2020. The symptoms included fever, malaise, a dry cough, and dyspnea, known as viral pneumonia. The virus is spread by small droplets generated by infected people when they breathe, sneeze, or cough. Depending on the temperature and composition of the surfaces, these microscopic particles are thought to linger on food surfaces, food packaging, or items for a long time (Liu et al., 2020). As a result, the WHO has undertaken non-pharmaceutical measures, such as the prevention of public occasions and recreational activities, restriction of movement and travel restrictions, and the use of personal protective equipment to minimize its spread. In a short period of time, such policies were demonstrated to be particularly effective in China, South Korea, and Singapore, pushing other countries to employ similar techniques to the entire degree feasible (Chitrakar et al., 2021). Today, the world is slowly recovering from the pandemic after introducing the vaccination to prevent the disease from spreading.

According to WHO, this pandemic is more than a public health crisis. It is a crisis that will influence every sector. Along with human health and wealth, the spread of the coronavirus outbreak affected the food manufacturing and consumer-packaged-goods (CPG) industry (Aday et al., 2020). Several manufacturing industries have borne the brunt of the outbreak, some operations being disrupted. According to Fremaux (2021), The COVID-19 pandemic, on the other hand, has put enormous demand on the packaged foods sector, which experienced a 5% growth. Due to the high demand, quality in the processing of products is essential to satisfy customers' demands while also improving the company's performance. High demand for packaged food products may result in a high percentage of defective products produced by the company if they are unaware of its product quality (Alldredge et al., 2021).

Product quality, in addition to pricing, becomes quite important when consumers buy a product. Improvements to product quality to achieve a near-zero defect level necessitate a significant financial investment. Companies today strive for increased process capability while lowering the cost of poor quality (COPQ). COPQ refers to the cost of delivering poor-quality products or services to customers. COPQ is also the cost borne to cope with process failure and damage (Purwoharsojo et al., 2020). According to statistical data, COPQ is less than 10% of sales for companies at the Six Sigma level, 15% to 20% of sales for companies at the four sigma level, and 20% to 30% of sales for companies at the three-sigma level. A project-based approach based on the Six Sigma DMAIC method is one of the famous approaches to lowering COPQ (Anupama, 2017).

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The Six Sigma approach improves current processes and has been proved effective in lowering costs, enhancing production cycles, minimizing defects, increasing customer satisfaction, and raising profitability throughout every marketplace and many global organizations (Anupama, 2017). Six Sigma is a systematic technique for problem-solving featuring five phases: *Define, Measure, Analyze, Improve, and Control* (DMAIC). The DMAIC method is simple and relevant to all contexts, with defined goals, actions, and outcomes for each phase. Six Sigma aims to improve the quality of data instead of quantity, and it employs analytical techniques in a practical format. Company issues are identified, and measures are created during the define phase. In the measure phase, the current level of performance is anticipated after taking appropriate actions concerning any deficient measurement system and ensuring adequate process stability. After identifying possible factors, the analysis phase focuses on identifying and verifying the root causes. Root cause analysis (RCA) refers to finding the root cause using a structured approach. Next, the improvement phase helps identify and implement solutions, while the control phase ensures that the results are sustained. During the analysis phase, widely known tools such as cause and effect diagrams (CED), why-why analysis, tree diagrams are used to identify the root causes (Sarkar et al., 2017). Whether the source of the problem is an inefficient process or a defect issue, the true impact of incorporating Six Sigma elements into the manufacturing process to achieve the highest quality products that satisfy customers is required (Omoush, 2020).

One of the growing research themes in Six Sigma is the integration of Six Sigma with the Quality Management System ISO 9001. There are logical connections between Six Sigma and ISO 9001 and benefits from their integration. Implementing a Six Sigma effort can assist a company in improving the efficiency and effectiveness of its business processes and moving closer to gaining ISO 9001 certification. The ISO 9000 set of standards, on the other hand, lays the way for Six Sigma adoption and serves as a valuable reference for people participating in Six Sigma operations. Both methods place a premium on actions that promote continuous development. Six Sigma DMAIC is based on the PDCA continuous improvement cycle. Hence the DMAIC approach may meet the standard requirements for continuous improvement (Marques et al., 2013).

As a result, in this research, the quality of production processes and defect factors were investigated to illustrate the real impact of using the Six Sigma approach with Quality Management System ISO 9001 to achieve high-quality products by improving the production process in the food industry. The main issue addressed in this study is the need to focus on the quality production process and defect factors while implementing Six Sigma methods. Furthermore, the proposed new Standard Operating Procedure (SOP) aims to reduce defects while also significantly improving corrective strategies and actions. As a result, the overall quality of the products will enhance.

INDUSTRY BACKGROUND

Since the beginning of 2020, the globe has been seeing unexpected events. COVID-19 has impacted every major industry over the last two years. The food industry has been the most severely impacted compared to other sectors. While many restaurants are struggling financially, Consumer Product Goods (CPG), packaged food and beverage brands are doing well (Conway, 2021). The food industry is among the main sectors in the world. This industry is a crucial sector of the global economy that faces numerous challenges in providing a diverse range of high-quality products that meet customer needs (Costa et al., 2018).

The food sector has progressed from raw material sourcing, procuring, and managing to food manufacturing, delivery, and consumption in today's fast-paced world. However, these advancements have begun to increase the rate of food production defects. A simple error in a food phase of production can have a significant impact on food quality which, as a result, could ruin consumer satisfaction. This makes food quality one of the most pressing issues in the twenty-first century. A new lifestyle gives consumers the right to buy safe, high-quality food, with the primary goal of improving life quality and health. Taking into consideration that the customer is always correct, especially when it comes to food. The failure to pay attention to the use of high-quality raw materials and the preparation of food processes that do not adhere to established standards creates a problem in which the quality of the finished products decreases. This issue could be solved by going through the current process of production used in the procedure. The food industry has become a major, diverse business with a complex network ranging from sourcing raw materials to production, packing, and distribution. As a result, food companies could not focus solely on product quality. Every company, regardless of sector, is working on it to help the economy recover. Most companies try to find a way to optimize the process to gain a competitive advantage, diversify by devising new strategies, creating decisions, and minimizing expenses. This is among the factors why the big sector, including the food sector, strives to develop and implement innovative methods and programs of high quality.

Adopting Six Sigma could significantly boost productivity and quality in many parts of the operation while maintaining a competitive advantage in the food industry. Unfortunately, there seems to be less implementation of Six Sigma in the food industry. It is not always only a technical concern when implementing new tools; it also depends on corporate rules, processes, culture, severe competition, high variable material prices, legal requirements, and quality management. The notion of quality control and continual improvement is critical in the food sector. Consumers want a wide variety of foods, tasty flavors that are simple to prepare and of high quality. Because of the importance of Six Sigma, all industries are switching their traditional methods of operation and implementing this new method. However, some food industry sectors try to keep conventional production methods alive to distinguish themselves from competitors and preserve their uniqueness. Figure 1 below illustrates the major Six Sigma elements in the food industry:

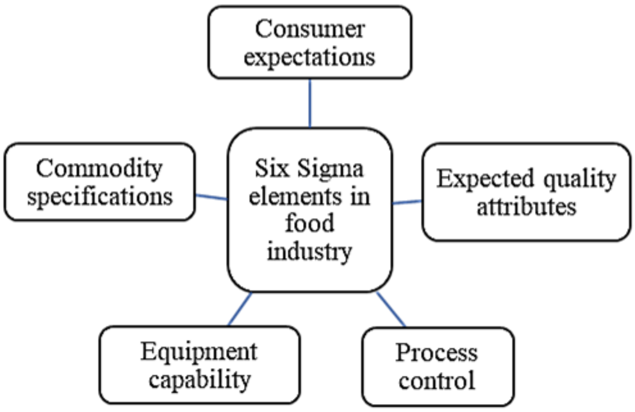

Figure 1. Six Sigma elements in the food industry.

Customer happiness, required quality attributes, process control, equipment capabilities, and commodity are all factors that apply scientific breakthroughs in the food sector. If any of these aspects are absent, the product will struggle, significantly impacting customers' contentment, complaints, ambiguous quality standard, incorrect monitoring procedures, high rate of wastage or delay in operation and lost revenue. According to certain studies, charges related to sluggish processing speed or performance to satisfy customer expectations and demand account for 30% to 50% of food business costs. Implementing Lean practices increased process cycle efficiency (PCE) from 5.02% to 17.46% (Costa et al., 2018). According to the data, the Six Sigma approach will assist the company in increasing productivity and product quality while decreasing defects and time.

Processes may be developed, monitored, evaluated, improved, managed, and eventually benchmarked against other facilities using the Six Sigma technique with the lowest costs. It increases process speed by lowering cycle time and productivity and the cost of capital spending. At the same time, it lowers defects and variances in the manufacturing process. As a result, when defects are reduced by 10%, the process speed increases by 40% (Nikoli, 2018). In other words, the Six Sigma design is the method appropriate for assisting in the design and delivery of new technology. It will consider form, fit, and functions to decrease variations, boost profits, and minimize defects and waste.

CONFECTIONERY AND PASTRY PRODUCTS IN FRANCE

Bakeries and pastries products play an important role in French culinary traditions, and the French are proud of their heritage. Along with cheese and wine, France is known worldwide for its authentic pastry assortment. The French are extremely concerned about the quality of their food, and they are even more concerned about the quality of their pastries. They put their hearts and souls into every pastry they bake, and their consumers can tell. The quality of confectionery and pastry products is critical, and any deficiencies in their products must be considered. For example, suppose a French customer receives macarons as a present and discovers a defect, such as cracked macarons. In that case, customers will be quite upset since they are highly demanding about the pastry's quality. Although cracked macarons are a common defect that always occurs with macarons, the company should make every effort to avoid mishaps. Such mistakes have the potential to tarnish the company's image. As a result, the company must emphasize all aspects of product quality, particularly in the confectionery and pastry products industry.

COMPANY BACKGROUND

ABC Company is a bakery started in 1996 and located in the Gare district in Valenciennes, France. ABC Company is a family business that competes in creativity in the kitchen with four hands to produce innovative and delicious pastries. They made and sold various confectionery and pastry products, such as cupcakes, chocolate, entremets, biscuit confectionery, ice cream, and pastries. ABC Company still adopts traditional methods in their confectionery and pastry production to maintain the originality of taste and uniqueness of their bakery compared to the industrial products available in the market. They feast on the house's sweets, which are always created with regard for tradition by using high-quality ingredients.

ABC Company is a small enterprise with 23 employees. The company has several departments in the production process, including the raw material preparation, production, quality control, packaging, shipping, and sales department. The owners of the ABC Company oversee ensuring that the quality of the products produced meets the standards and preferences of the consumer. Although the company continues to operate traditionally, they are not far behind in applying engineering technology to the production of their products. This helps to speed up the manufacturing process and to avoid human error. A few examples of the company's equipment for its operation include dough mixers and bowl lifts, commercial bakery ovens, pastry equipment machines, water meters and chillers, conveying system, and packaging equipment.

Their bakery is open from 7 a.m. to 7 p.m. from Tuesday to Sunday. They begin the manufacturing process as early as 5 a.m., and to retain the product's quality, several fresh pastry items, like croissants and baguettes, need to be made fresh every day. The company enjoys the sweet treats of the house and is always prepared with respect for tradition by selecting quality products. Furthermore, ABC Company sources raw materials from top and reliable local vendors. ABC

Company focuses heavily on producing high-quality products, as stated in their company motto, *"create emotion and quality at your fingertips"*.

ABC Company is chosen to conduct a case study because their company is a small size business. Identifying the problem and the root cause of the problem is simple but meaningful. Apart from that, ABC Company has never experienced any problems related to the quality of their products before. However, the Covid-19 pandemic that has been going on for two years has had a significant impact on their products and the quality of the products produced.

RESEARCH PROBLEM

Issues that need to be explored in this study are eliminating defective products and enhancing product quality, both of which have been a concern for ABC Company. Since the outbreak, The company's confectionery and pastry products have been in high demand. This condition required bakers to labor harder and faster than usual to meet customer demand, particularly during the month of major French holidays, such as Mother's Day, Father's Day, Easter Day, etc. Customers must purchase confectionery and pastry products from their bakery as gifts for their loved ones due to government restrictions imposed during the pandemic, which prevented people from assembling in large numbers. Consequently, ABC Company's macarons product suffers from a high defect rate. The existence of defective products in the manufacturing process and finished goods will result in increased production costs for the business, and customers will be disgruntled with the products produced. They will move to rivals' products of higher quality. The macarons product was chosen for this case study because, in May 2021, this product caused a high defect rate as much 83% of the production of macarons product equal to 181.870 pcs of macarons product are rejected. ABC Company estimated a loss of more than 300,000 euros. On top of these problems that arise, ABC Company had to focus on improving the quality of their macarons product. Thus, this study aims to determine how the company's production process is implemented to preserve the quality of the finished product produced and its relationship in determining the variables that must be addressed to improve the company's performance.

RESEARCH OBJECTIVES

ABC Company's case study focuses on the product quality and the control variables that impact the product quality of macarons. The objectives of this study as stated below:

i. To optimize the quality of the production process.
ii. To determine the main factor that causes the defect of the finished product.
iii. To propose a new Standard Operating Procedure (SOP) using the proposed enhancements.

SCOPE OF STUDY

Since the Covid-19 outbreak, ABC Company has seen many defects in one of its products (macarons). As a response, the goal of this case study is to use the Six Sigma approach to improve the quality of the production process. Furthermore, this case study will assist the ABC Company in determining the elements that influence the quality of the production process and ultimately suggest a new Standard Operating Procedure (SOP) to help the company improve its quality production process in the future. This case study is intended in a bakery of ABC Company and will focus on the process of making macarons. This research employs the Six Sigma DMAIC (Define-Measure-Analyze-Improve-Control) approach as an improvement tool for the macaron production process. This study does not cover the complete macaron production process but focuses on the piping, baking, and cooling shell procedure and the filling process. In the measure phase, the quality level of the macarons process will be calculated first to see if it achieves the Six Sigma level or otherwise. Critical to Quality (CTQ), Cost of Poor Quality (COPQ), and Defects per Million Opportunities (DPMO) are some of the data required for the Six Sigma DMAIC approach. The data set provided is for May 2021 and the data utilized is the number of macarons produced and the proportion of each defect. The data consists of the various categories of defects that occur and their relative percentages. The characteristics of macaron defects will be determined during the analysis stage, and the control parameters for this production process will be utilized to carry out the experimental design utilizing the Taguchi Method of DOE (Design of Experiment). The company owners were responsible for providing data information significant to this case study. The research consists only of offering guidance on improving the production process for enhancing and regulating the quality of macarons products using the DMAIC (Six Sigma) approach.

SCOPE OF STUDY

Cost of Poor Quality (COPQ)

Poor product quality will cause a loss of value for both manufacturers and consumers. Companies with three-sigma processes will lose 20–40% of their overall sales because of quality costs. Companies with a sigma level of six-sigma, on the other hand, will only lose less than 10% of their revenues due to quality costs. Each one-sigma improvement or shift . results in a 10% increase in sales profit. Table 1 depicts the link between sigma level, Defect-Per-Million-Opportunities (DPMO), and Cost of Poor Quality (COPQ) (Kumar et al., 2018):

Table 1. Six Sigma level comparison.

Sigma Achievement Level	DPMO	Competitive Level	COPQ
6- Sigma	3.400 (99.99%)	World-Class	< 10% of sales
5- Sigma	233.000 (99.97%)	Significantly higher than average	10% - 15% of sales
4- Sigma	6.210 (99.38%)	Industry average	15% - 20% of sales
3- Sigma	66.807 (93.32%)	Industry average	20% - 30%
2- Sigma	308.500 (69.15%)	Below industry average	30% - 40% of sales
1- Sigma	691.500 (30.85%)	Uncompetitive	> 40%

Defect Per Million Opportunities (DPMO)

Six DPMO is an abbreviation for Defects-Per-Million-Opportunities. Nonconformities per Million Opportunities (NPMO) is another name for it. The number of faults in a sample is multiplied by one million to get the total number of defect possibilities. According to the Six Sigma technique, there are 3.4 flaws for every million opportunities. The DPMO is a long-term indicator of process performance. It is a measure of a process's error rate. The measurement indicates how good the procedure is at making errors. It provides the company with a realistic image of the production process's efficiency. Depending on the Defects-per-Million-Opportunities, the company may decide if the Six Sigma approach is required to enhance the process of production and minimize the opportunities' number of defects per million products. If the DPMO is too significant, the company risks negatively impacting client satisfaction, which will harm their business. Six Sigma business improvement programs aim to reduce mistakes and increase customer satisfaction, fostering a healthy business. This refers to the term DPMO in the Six Sigma methodology (Admin, 2020).

The Approach of Six Sigma)

Six Sigma is a collection of approaches and techniques for streamlining and optimizing processes. Bill Smith, a Motorola engineer in 1986, was the first to introduce it. General Electric CEO Jack Welch made it a centerpiece of his corporate strategy in 1995. The Six Sigma adaptation creates a process in which 99.99966% of all opportunities to generate some aspects of a part are predicted to be defect-free statistically. The term Six Sigma was coined to characterize the statistical modeling of manufacturing processes. A Sigma evaluation may be used to define how many standard deviations of a normal distribution the proportion of defect-free outcomes corresponds to when a manufacturing process produces a yield or percentage of defect-free items (Girija, 2020).

Six Sigma's characteristics include customer-oriented implementation, which means that the Six Sigma implementation is focused on the customer's needs. Six Sigma is a methodology for improving process quality through the systematic use of DMAIC *(Define-Measure-Analyze-Improve-Control)*. Six Sigma deployment necessitates collaborative efforts to regulate and enhance production quality (Tampubolon et al., 2021). Six Sigma implementation aims to improve processes and constantly obtain reliable and consistent outcomes: Six Sigma adoption necessitates the application of tools and procedures to define and evaluate each stage of a process or project. Six Sigma does indeed have some advantages that assist in enhancing the quality of a process or project's output. It also helps identify and eliminate defect causes, as well as the reduction of process cycle time. Six Sigma implementation aids the organization in lowering costs, boosting excellent customer experience, and generating revenues (Utami et al., 2021).

There are eight basic steps in implementing Six Sigma, namely identification, definition, measurement, analysis, improvement, control, standardization, and integration. (integrated). The Measure-Analyze-Improve-Control step is at the foundation of this approach. On the other hand, the definition process is generally included in the core of a six-sigma plan, so the phases become Define-Measure-Analyze-Improve-Control. The DMAIC stages in the Six Sigma approach are represented in Table 2 (Girija, 2020):

Table 2. DMAIC stages.

DMAIC Stages	Description
Define	This stage clarifies problems, goals, and processes. Create a problem statement that is as detailed and fact-based as possible, concentrating on what can be seen and collated rather than on assumptions or assumptions.
Measure	This stage establishes the problem's core and analyzes it. Verify or analyze the problem and begin exploring its root cause, pay attention to the output created and its impact on system users, and determine the most significant components of the problem so that analysis and alternatives are well focused.
Analyze	This stage refers to the root cause analysis. Examine processes and data to uncover potential reasons, then select possible causes and confirm them via analysis.
Improve	This stage includes the transformation, selection, and implementation of solutions. It is finding ideas that may assist us in getting to the core of the problem and achieving our objectives, determining which ideas are prospective solutions, and selecting the most appropriate solution with the least expense and difficulty.
Control	This stage involves addressing problems after installation, establishing standards to sustain performance effectiveness, and performing reviews.

Critical to Quality (CTQ)

Critical to Quality (CTQ) is the primary quantifiable features of a product or process in which quality standards must fulfill the customer's needs. They relate improvement or design efforts to client needs. CTQ is the features of products or services defined by internal or external customers. They contain the upper and lower specification limitations and any other aspects of the product or service. A CTQ must typically be interpreted from the customer's qualitative expression to workable quantitative business requirements. A process's output might be in the form of products or services. The output variable might take the form of delivery time or product dimensions. The essential output elements are often classified according to their influence on the impact of the area, notably important for quality, cost-effectiveness, a necessity for delivery, and process critical. CTQ is a specified quality characteristic that should be closely tied to the customer's specific needs and is developed directly from the output and service requirements. The precise criteria of the customer must be adequately translated into the quality attributes set by the organization's management (Lemke et al., 2021).

Taguchi Method of Design of Experiment (DOE) for Quality Control

In the 1950s, a Japanese engineer and statistician named Genichi Taguchi developed the Taguchi method while working on a telephone-switching system for a Japanese firm called Electrical Communication Laboratory. He wanted to increase the efficiency of production by using statistics. Taguchi's ideas began to acquire traction in the Western world in the 1980s, becoming well-known in the United States after success in his native Japan. His methods have been implemented by major worldwide corporations such as Toyota Motor Corp., Ford Motor Co., Boeing Co., and Xerox Holdings Corp. The Taguchi method of quality control is an engineering strategy that stresses the roles of R&D, product design, and development in reducing defects and failures in the production process (Kenton, 2021).

The Taguchi approach entails using a systematic design of experiments (DOE) to minimize variation in a process. The main purpose of the technique is to create a better-quality product and cost-effectiveness. Taguchi established a technique of experimental design to evaluate the influence of the performance process' mean and variance, which reflects how effectively the process works. Taguchi recommends arranging the factors that impact the process and the levels at which they have been modified using Orthogonal Arrays. The design of experiments (DOE) uses statistics to experiment systematically. A series of tests are devised in DOE to evaluate the reasons for variation in the output response by purposefully varying the variables input, either product or process. Using variance analysis, the data obtained by the Taguchi design of trials may be used to select new variable values to enhance the performance feature. The data from the arrays may be analyzed using plotting and visual analysis, ANOVA, bin yield and Fisher's exact test, or the Chi-squared test for significance (Fraley et al., 2021)

The DOE application has a few advantages: an enormous amount of data may be gathered with limited resources. It also helps in the more precise estimation of the effect of each element (variable) on the output, and it is a method for calculating the interactions between process variables in a systematic way. By the end of the twentieth century, DOE had been bundled with a structured business development initiative known as Six Sigma. It was no longer considered a stand-alone technique. Furthermore, the Six Sigma literature placed a greater emphasis on DOE at this time. DOE is a useful tool for learning about and optimizing goods and process factors. It is both rapid and cost-effective (Davis et al., 2018).

Integration of Six Sigma With Quality Management System (QMS) ISO 9001

A quality management system (QMS) is a well-organized system that records procedures, techniques, and responsibilities for achieving quality policies and objectives. QMS helps a company coordinate and guide its actions to fulfill customer and regulatory requirements while enhancing its effectiveness and efficiency (ASQ, 2021). While in the other hand, ISO 9001 is a worldwide standard that establishes the specifications for a quality management system (QMS). Companies utilize this benchmark to demonstrate that they can consistently offer products and services compliant with consumer and regulatory guidelines. ISO 9001 was first published in 1987 by the International Organization for Standardization (ISO), which is made up of national standards organizations from over 160 nations. The latest edition of ISO 9001, known as ISO 9001:2015, was released in September 2015 (ASQ, 2021).

The ISO 9001 Quality Management System (QMS) is the most widely used quality management model globally, with over 1.1 million certifications issued to industrial and service organizations worldwide. Quality management has evolved through the following phases: quality control, quality assurance, total quality, and, lastly, the emergence of business excellence models. ISO 9001 is a set of best practices for quality management systems that are anticipated to produce substantial results if the standard is followed consistently. According to the standard, ISO 9001 seeks to guarantee that businesses manufacture goods that meet the needs of their customers, achieve customer satisfaction, and continuously enhance the efficacy of their quality management system (Salazar et al., 2019).

Since the standard's 2000 revision, ISO 9001 has included Total Quality Management ideas into the standard, emphasizing process and performance rather than paperwork. Furthermore, ISO 9001 embraced the PDCA approach *(Plan Do Check Act).* ISO 9001 is founded on eight quality management principles: customer satisfaction, employee engagement, process approach, system management approach, continuous improvement, actual approach to decision making, and mutually beneficial supplier relationship.

The eight quality management concepts were included in ISO 9001's five core criteria. The first criteria, quality management system, refers to the organization's responsibility to manage quality management system processes and documentation. The second criterion, management responsibility, relates to senior management's obligations for the quality management system. The third need, resource management, calls for organizations to manage the resources required by the quality management system. The fourth criterion, product realization, is related to the basic process commitment of the company. The fifth requirement, measurement, analysis, and improvement, relates to a company's responsibility to measure, analyze, and improve its quality management system (Sumaedi et al., 2015), which relates to the Six Sigma approach.

The continuous improvement approach used by ISO 9001 and Six Sigma was identical. Both methods place a strong emphasis on actions that promote continuous improvement. Six Sigma DMAIC is based on the PDCA continuous improvement cycle. Hence the DMAIC approach can be utilized to meet the standard's requirements for continuous improvement. ISO's process model emphasizes the need for continual improvement and provides a comprehensive strategy for meeting customer satisfaction. Six Sigma projects are one of the most effective ways to increase the company's performance. Six Sigma also has the added benefit of assisting ISO 9001 continuous improvement initiatives. The eight principles, the process model, and the ISO 9001 standards all work together to offer a complete and useful framework for improvement (Marques et al., 2013).

RESEARCH METHODOLOGY

This study employed both qualitative and quantitative research methods to gather information on improving product quality and production processes through the integration of Six Sigma and the ISO 9001 Quality Management System. In this research study, ethnography, interviews, and a literature review were used to acquire qualitative data. The interview approach was used on individuals in charge, the focus point from the quality management department of the bakery of ABC Company. The relevance of this approach is that clear information may be received since it involves direct contact and vocal discussion between the parties involved. On the other hand, quantitative data gathering approaches were used, and experiments. Data collecting methods are offered as guidelines for gathering data information following the study's scope and objectives. The investigation began with a specific observation inside the bakery's macarons production kitchen of the bakery to acquire information on how ABC Company's operations corresponded with the Quality Management System ISO 9001 policy and how the company followed the macarons production work standard. The procedure of gathering information continues with an interview with the person in control of that ABC Company. They were also in charge of providing the statistical data needed to carry out this case study. The entire conversation is taken to preserve the data information and confirm the legitimacy of the company's information. The experiment was then conducted to establish the situation in which variables are controlled and manipulated to establish cause-and-effect relationships. Numbers are the foundation of quantitative data. Simple algebra or more complicated statistical analysis is performed to uncover similarities or trends in the data. The findings are presented in graphs and tables. To compute items like Defect Per Million Opportunities (DPMO) and Sigma Level, P- Chart, Pareto Diagram, and Design of Experiment (DOE) of Taguchi Method, applications like Excel and Minitab 18 are utilized.

CASE ANALYSIS

The DMAIC (Define-Measure-Analyze-Improve-Control) approach is applied to develop solutions in this study. Figure 2 illustrates the steps of data processing:

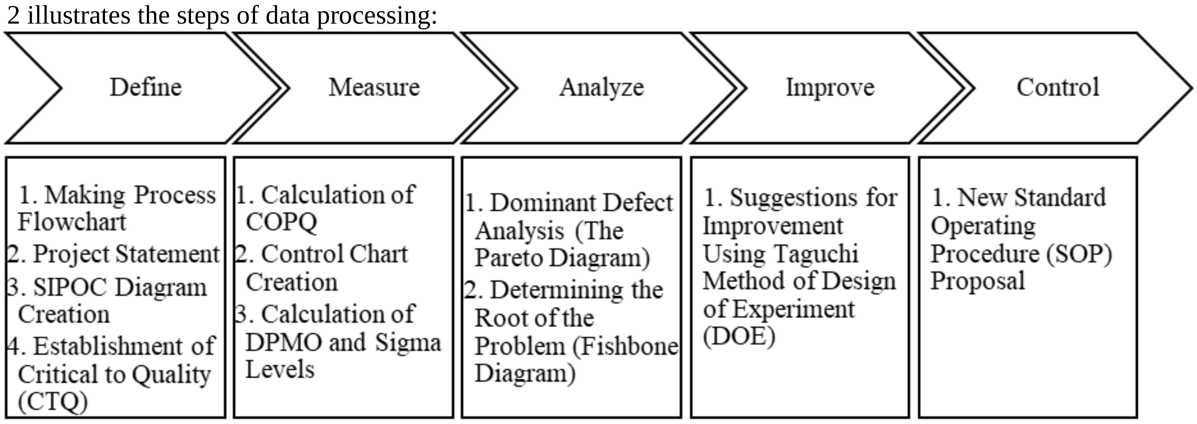

Figure 2. The summarization of data processing stages.

Several phases of data processing and analysis were carried out utilizing the DMAIC approach based on the data received during the data collecting stage, which consisted of five stages as follows:

Define Stage

The defined stage is creating the process flow chart, project statement, suppliers, inputs, process, outputs, customer (SIPOC) diagram, and critical to quality (CTQ).

Making Process Flowchart

The process flow chart creation is a process flow diagram developed at this step, which is useful for observing the manufacturing process activities. This case study goes through the selection process of macarons production; several procedures to make macarons include mixing the ingredients, piping, baking and cooling shell, filling process, packaging and packing, and warehousing.

Project Statement

At the project statements stage, an overview of the project to be investigated is provided in the form of the project's background and the occurring difficulties. Furthermore, it specifies the scope of the project, the project objectives, and the timeframe for project implementation.

SIPOC Diagram Creation

SIPOC diagram is used to describe the interactions of numerous parties engaged in sourcing raw materials, manufacturing the finished product, and packaging it. The SIPOC diagram depicts the flow of raw materials into final goods, with suppliers, inputs, processes, outputs, and customers shown in each process.

Establishment of Critical to Quality (CTQ)

The establishment of CTQ is responsible for determining the product's customers' requirements. This power of buyers will serve as the foundation for developing the CTQ or the product's quality attributes.

Measure Stage

The defined stage consists of creating the process flow chart, project statement, SIPOC diagram, and CTQ.

Calculation of Cost of Poor Quality (COPQ)

The COPQ calculation is used to assess the expenses spent by ABC Company because of a defective product.

Control Chart Creation

The control chart is developed to determine whether the process is still within control limitations. Process capability calculation determines the process's ability to produce items that fulfill customer requirements.

Calculation of Defect Per Million Opportunities (DPMO) and Sigma Level

Lastly, the calculation of DPMO and Sigma levels involves computing the DPMO value of the chosen product type and translating it to a sigma level to determine the product's quality level.

Analyze Stage

The analysis stage consists of dominant defect analysis (The Pareto Diagram), determining the root of the problem (Fishbone Diagram), and Design of Experiment (DOE) using Taguchi Method.

Dominant Defect Analysis (The Pareto Diagram)

The Pareto diagram is used to analyze dominant defects. Creating a Pareto diagram is to identify the most common type of fault that occurs in the specified product category.

Determining The Root of The Problem (Fishbone Diagram)

While the Fishbone diagram helps to identify the root cause. The Fishbone diagram is designed to identify the elements generating faults by utilizing five factors, including man, method, machine, material, and the environment, by each type of defect that arises.

Improve Stage

The improvement stage will provide suggestions for improvement in the ABC Company for the macarons production process using Taguchi Method of Design of Experiment (DOE).

Suggestions for Improvement Using Taguchi Method of Design of Experiment (DOE)

Design of experiment (DOE) of the Taguchi method helps investigate processes where the result is dependent on many variables and inputs. The conditions during the production process affected the values of quality characteristics of macarons. Changing the baking period and temperature of the samples and the velocity mixing type of the ingredients in the samples had a substantial impact on quality characteristics. The elements of the experimental process are the conditions listed above for this experiment. Any non-linear relationship was considered because the goal of this experiment was to optimize the macarons' product process. As the experiment settings remained stable, the technique was carried out in a controlled atmosphere. This assures that external influences do not affect the results. The only conditions that vary in their values during the experiment are three control parameters: mixing level, baking time, and oven temperature. Based on the same formula that is usually used to manufacture macarons, the quantities of ingredients remained consistent throughout all experiments. Table 3 outlines the experimental design levels and control elements used in this case study:

Table 3. Control variables and level of the experimental design.

Variables	Symbols	Level		
		1	2	3
Mixing Level of Mixing (rpm)	A	80	160	250
Time of Baking(min)	B	8	12	15
Oven Temperature (°C)	C	185	190	203

For the Taguchi method DOE, the L9 Orthogonal Array Experiments were used. An Orthogonal Array is a structure of integers that are organized in rows and columns. Each row reflects the levels of the stated components in a single experiment, while each column represents a distinct aspect that determines the outcome. At this point, a corrective action plan will be established to outline the remedies provided. An experimental design may be swiftly formed by allocating variables to columns in the OA and then corresponding the various symbols of columns with the variable levels. A balanced characteristic of OA is that each factor configuration appears the same amount of times for each set of many other variables in the tests. The L9 (33) OA was chosen for the controllable factors because of the economical orthogonal design to appease three components at three levels, as shown in Table 4. The number of experimental runs is determined by the L9(33) array:

Table 4. Experimental layout using L9 (3^3) Orthogonal Array (OA).

Experimental Trial	Parameters		
	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

To investigate the primary effects, nine trials of experiments with various set of variables should be done. To avoid any perceptual unfairness, the studies were conducted in a randomized sequence. Table 5 summarizes the combinations of control factors used in each of the nine studies:

Table 5. Taguchi L9 (3^3) Orthogonal Array (OA) design.

Experimental Trial	Mixing Level (rpm)	Baking Time (min)	Oven Temperature (°C)
1	80	8	185
2	80	12	190
3	80	15	203
4	160	8	190
5	160	12	203
6	160	15	185
7	250	8	203
8	250	12	185
9	250	15	190

Control Stage

Control Stage will propose the new Standard Operating Procedure (SOP) using the proposed enhancements:

DISCUSSIONS AND RESULTS

The study intends to identify and examine the macarons production process in the ABC Company. The company visit is undertaken to gain a thorough understanding of the macarons processing process, both technically and practically, and to gain a thorough awareness of the difficulties and factors that affect quality. The goal is to collect information on the macaron's production flow process and quality performance for analysis. In this case study, the DMAIC *(Define-Measure-Analyze-Improve-Control)* is carried out stage by stage.

Define Stage

Flow Chart Creation

Figure 3 illustrates the flow of the production process for macarons. Table 6 shows the description of the flow sequence of the current macarons production process:

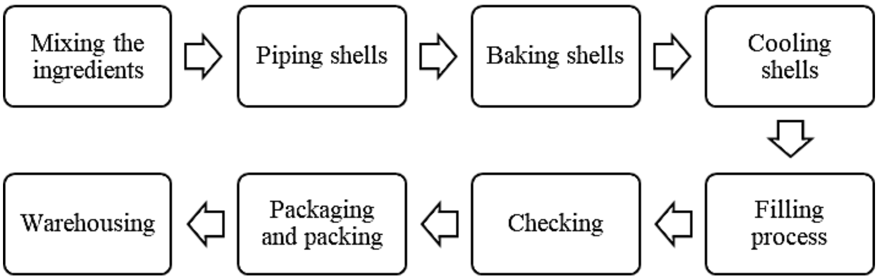

Figure 3. Flowchart of the current production process of macarons product.

Table 6. Process flow of macarons current production process.

No.	Process	Picture	Descriptions
1	Mixing the ingredients		The process of weighing and mixing raw ingredients to make macaron batter. The raw ingredients involved were eggs, granulated sugar, icing sugar, and almond flour. Select mixing type: The process of selecting the mixing type which one is for low, two is for medium, and three is for high.
2	Piping macarons shells		The process entails piping the macarons shell batter onto the trays following the standard size.

			
3	Baking macarons shells		The macarons shells were baking in the oven.
4	Cooling macarons shells		This process is allowing the macarons shell to cool after the baking.
5	Filling process		After cooling, the macaron shell proceeds to the filling process, which is the process of adding cream flavors to the macarons shell.
6	Checking		At this point, the bakers observe the overall condition and the quality of the macarons before weighing the macarons.

Project Statement

The project statement is involved the business case which customers are still complaining about the presence of defective products in the boxes of products that have been sent to them. As a result, the inspection process must be improved so that defective products do not reach customers' hands. The problem statement is identified. In May 2021, the percentage of defects in macarons products is 16.50%. Defects cause cost losses to be borne by ABC Company, which is approximately 23,100 units.

SIPOC Diagram Creation

SIPOC diagram creation consists of suppliers, input, processes, outputs, and customers. The production process consists of checking the quality of raw ingredients, weighing, and mixing the ingredients, preparing the batter solution, piping the batter on the trays, baking, cooling the macarons shell, checking products, and packaging products. The input and output flow of each existing production process will be explained in the SIPOC diagram, as follows in Figure 4:

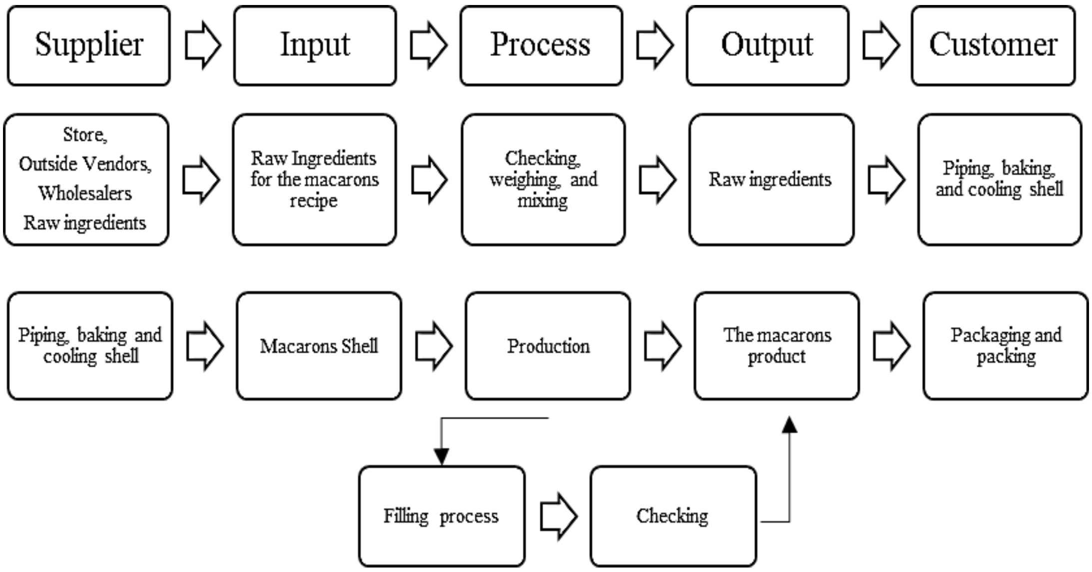

Figure 4. SIPOC diagram of macarons products.

Establishment of Critical to Quality (COPQ)

On the other hand, Critical to Quality (CTQ) on macarons products is determined based on interviews with the ABC Company's owner. There are four categories of CTQ on macarons products, namely, appearance, dimension, weight, and taste. Appearance category criteria are indicated by the outer appearance of the macarons product itself and visually identified, such as the density of the macarons and color. Each macaron must be prepared following the stated dimensions. Round macarons are typically 3.5 cm in diameter. However, the size of macarons shells can be piped larger or smaller. Each baking sheet will provide 32 circles (16 in pair of macarons), all of which are designed for the typical macaron size of 3.5 cm with a 2 cm gap between each. The bakers must ensure that the weight of the macarons reflects the weight listed on the packaging. In terms of flavor, macarons provide a standardized flavor consistent with the previous tastes. The categories of defects in the product can be identified as a potential CTQ cause of defects in the macaron's product. Table 7 indicates that each of the eight types of defects has its characteristics and differences:

Table 7. Critical to Quality (CTQ) of macarons product.

Characteristics of Defects	Conditions	Characteristics of Defects	Conditions
Flat Crispy		No bottom	
No feet		Bumpy	
Cracked		Lopsided	
Hollow		Spread feet	

Measure Stage
Calculation of Cost of Poor Quality (COPQ)

Calculation of Costs of Poor Quality (COPQ) is based on data on the number of defects that exist in the macarons production process, and it can be calculated the costs incurred due to poor quality based on:

Total number boxes contain defects = 1,155 boxes, each box contains 20 pcs
Total defects in pcs = 1,155 boxes x 20 pcs = 23,100 pcs

17% of existing defects can still be sold out of the total amount of existing defects. As much as 83% of all defects result in losses for the ABC Company, hence the total number of items that result in losses is computed as follows:

Total defects = 23,100 pcs
23,100 x 83% = 19,173 pcs
Cost per Unit =1.80 Euro
COPQ = Cost per Unit x Total Defect
COPQ = 1.80 Euro x 19,173 = 34,511.40 Euro

So, in May 2021, ABC Company will have to pay 34,511.40 Euro in expenditures because of a defective product:

Control Chart Creation)

Creating a P control chart is useful whether the situation is within control limitations. Based on the ABC Company's historical data, which data on the amount of production and data on the number of defects from macarons products which are attribute data and have a different number of samples in each data collection, the control map mapping is carried out with the P control map. Table 8 shows the defect data for the macaron's product in May 2021, and the proportion calculation is calculated using the following equation:

Proportion data number 1,2,3,…. = Total Defect ÷ Total of Production

Microsoft Excel and Minitab are used to determine the Control Limit (CL), Upper Control Limit (UCL), and Lower Control Limit (LCL). The formula for CL, UCL, and LCL is shown below:

$$\text{Control Limit (CL)} = \text{P} = \frac{\sum \text{Pn (Total Defect)}}{\text{n (Total Production)}}$$

ΣPn = Total Defect (Boxes)
n= Total Production (Boxes)

$$\text{Upper Control Limit (UCL)} = \text{P} + 3\sqrt{\frac{\text{P}(1-\text{P})}{\text{n (Total Production)}}}$$

$$\text{Lower Control Limit (LCL)} = \text{P} + 3\sqrt{\frac{\text{P}(1-\text{P})}{\text{n (Total Production)}}}$$

Table 8. Defect data for the macarons product in May 2021.

No. of Data	Total Production (Boxes)	Total Defect (Boxes)	Proportion	CL	UCL	LCL
1	350	50	0.14286	0.16500	0.224521305	0.105478695
2	350	95	0.27143	0.16500	0.224521305	0.105478695
3	350	30	0.08571	0.16500	0.224521305	0.105478695
4	350	52	0.14857	0.16500	0.224521305	0.105478695
5	350	60	0.17143	0.16500	0.224521305	0.105478695
6	350	32	0.09143	0.16500	0.224521305	0.105478695
7	350	45	0.12857	0.16500	0.224521305	0.105478695
8	350	47	0.13429	0.16500	0.224521305	0.105478695
9	350	35	0.10000	0.16500	0.224521305	0.105478695
10	350	36	0.10286	0.16500	0.224521305	0.105478695
11	350	55	0.15714	0.16500	0.224521305	0.105478695

No. of Data	Total Production (Boxes)	Total Defect (Boxes)	Proportion	CL	UCL	LCL
12	350	85	0.24286	0.16500	0.224521305	0.105478695
13	350	46	0.13143	0.16500	0.224521305	0.105478695
14	350	48	0.13714	0.16500	0.224521305	0.105478695
15	350	57	0.16286	0.16500	0.224521305	0.105478695
16	350	95	0.27143	0.16500	0.224521305	0.105478695
17	350	69	0.19714	0.16500	0.224521305	0.105478695
18	350	75	0.21429	0.16500	0.224521305	0.105478695
19	350	80	0.22857	0.16500	0.224521305	0.105478695
20	350	63	0.18000	0.16500	0.224521305	0.105478695
Total	7000	1155	0.16500	0.16500	0.178309368	0.151690632

Figure 5 shows that 8 data are outside the specified specification limits. The control chart is outside the statistical control due to the varying percentage of defects that occur.

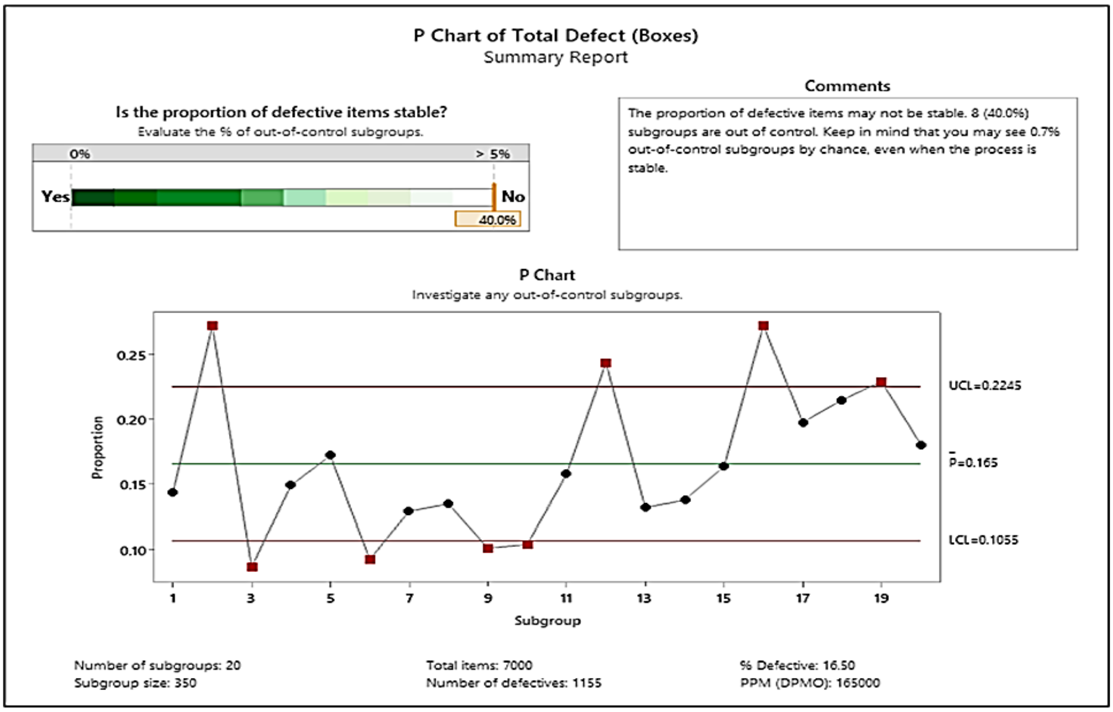

Figure 5. P-Control Chart of the total defect.

P=0.1650; UCL=0.2245; LCL= 0.1055 is obtained from the P-Chart. The capability process for P-Chart is calculated using the data from figure 5 shown below:

Capability Process (CP) = 1 – P = 1 – 0.1650 = 0.8350

Control is required since the process capability reaches 83.50% in a controlled process, where less than one is an adverse value.

Calculation of Defect Per Million Opportunities (DPMO) and Sigma Level

The Minitab of the P Chart was used to identify DPMO;165000 automatically. The Sigma level was computed as follows:

$$Level\ Sigma = normsinv\left(\frac{1000000 - DefectPerMillionOpportunities(DPMO)}{1000000}\right) + 1.5$$

$$normsinv\left(\frac{1000000 - 165000}{1000000}\right) + 1.5$$

The results of the Six Sigma calculation are 2.50, which the sigma value is still far from reaching a perfect sigma value of 6, so it is still necessary to identify and analyze the causes of the process that causes product defects.

Analyze Stage

Dominant Defect Analysis (The Pareto Diagram)

The analysis of dominant defects based on the data obtained is the number of product defects shown in Table 9:

Table 9. Total characteristics of defects.

Characteristics of Defects	Defective	Percentage	Cumulative Percentage
Cracked	313	0.536878216	0.536878
Hollow	95	0.162950257	0.699828
No feet	94	0.161234991	0.861063
Spread	50	0.085763293	0.946827
Lopsided	31	0.053173242	1
No bottom	0	0	1
Flat Crispy	0	0	1
Total Defects	583	1	

The most prevalent defects that reflect each category can be identified in the Pareto diagram in Figure 6 by looking at the cumulative value:

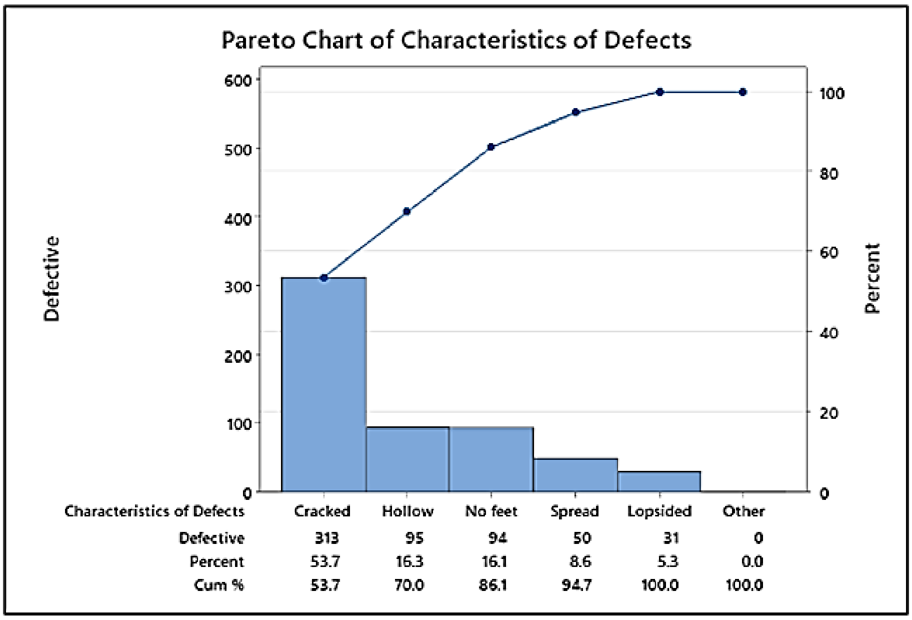

Figure 6. Pareto diagram of characteristics of defects.

According to the Pareto principle 80/20 rule, which claims that 20% of defects cause 80% of quality problems, the types of defects are chosen with a cumulative of 80% with the idea that with 80% they may represent all types of defects that occur. It can be observed that the most common defects are cracked (53.7%), hollow (16.3%), and no feet (16.1%). These three types of defects will be prioritized in handling the problem.

Determining The Root of The Problem

The next area that needs to be analyzed is using a Cause-and-Effect Diagram (Fishbone Diagram) to find the source of the problem. The cause-and-effect diagrams shown in Figure 7, Figure 8, and Figure 9 are used to discover the sources of faults using five causal factors*: man, machine, method, material, and environment*.

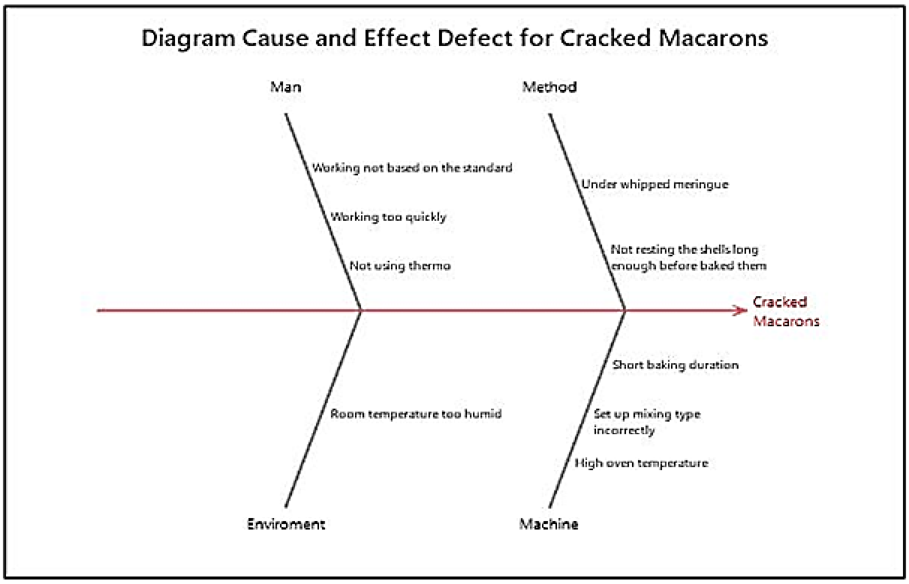

Figure 7. Diagram cause and effect defect for cracked macarons.

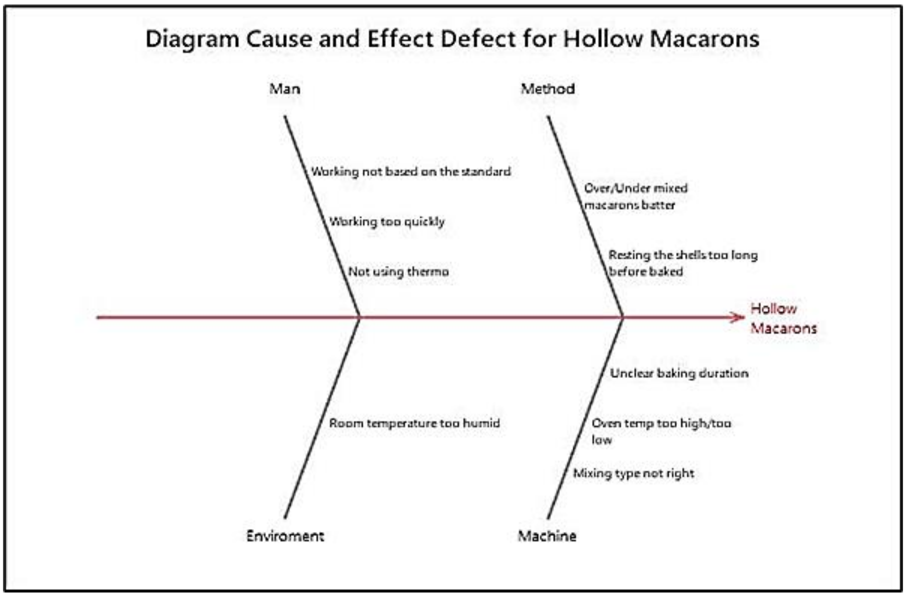

Figure 8. Diagram cause and effect defect for hollow macarons.

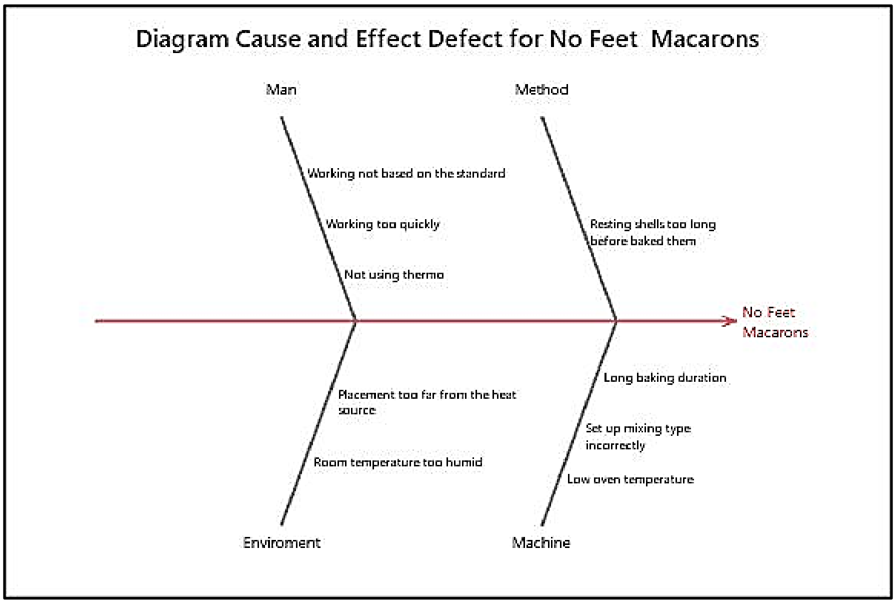

Figure 9. Diagram cause and effect defect for no feet macarons.

Improve Stage

DOE Using Taguchi Method

After determining the root cause of the macarons production process, improve stage is conducted using the Taguchi method of DOE to determine which major factors contributed to the macarons product defect. Three controllable variables have been found to have the potential to alter the quality of the macarons' production process. Each of the three parameters has three levels. Mixing level (rpm), baking time (min), and oven temperature (°C) are the three adjustable parameters that were chosen. Each controllable factor will be tested at three levels which are explained in Table 10:

Table 10. The levels of process parameters in DOE.

Process Parameters	Symbols	Level		
		1	2	3
Mixing Level (rpm)	A	80	160	250
Baking Time(min)	B	8	12	15
Oven Temperature (°C)	C	185	190	203

The total defect of macarons product from the experiment trial is shown in Table 12:

Table 11. The result of total defect from the experimental trial.

Experimental Trial	Total Defect
1	11
2	12
3	14
4	13
5	14
6	6
7	10
8	10
9	11

An orthogonal array is a mathematical approach provided by Taguchi's method that enables the analysis of the interaction among many design parameters with only a few trials done. The goal is to achieve the best process or product performance depending on the parameters specified. Taguchi supports using the ratio of Signal to Noise (S/N) to evaluate quality via orthogonal array-based studies. As part of the optimum setup analysis, the ratio of S/N is utilized to convert trial results into a value for the assessment criteria. The visual assessment of the output is used in this study to determine the quality characteristics of the macarons product. The reject rate should be kept to a bare minimum to assess and establish the best parameter parameters for the macarons production process. For this investigation, the bigger the ratio of S/N, the higher the quality attributes. The following is the formula for the S/N ratio that is calculated using Minitab Software, and the result is shown in Table 12:

$S/N = -10 \log (\Sigma (y^2 / n)$
y= total defect
n = number of trays involved (observation)

Table 12. Result calculation of S/N Ratio (Larger-The-Better).

n	Total Defect	S/N
1	11	20.82790
1	12	21.58360
1	14	22.92260
1	13	22.27890
1	14	22.92260
1	6	15.56300
1	10	20.00000
1	10	20.00000
1	11	20.82790

Main Effect Plot for Signal to Noise (S/N) Ratio and Means Response

A major effect plot depicts the mean response values at each design parameter or process variable level. The sign of the major effect indicates whether the average response value grows or falls. The scale of the effect reflects how strong it is. If a design or process parameter has a positive influence, the average response is higher at the high level of the parameter setting than at the low level. The average response at the low-level setting of the parameter is larger than the average response at the high-level setting if the effect is negative. The S/N Ratio charts for the macarons production experiment are shown in Figure 10. The higher the ratio of S/N, the better the quality in general:

Response Table for Signal to Noise Ratios

Larger is better

Level	Mixing Level (rpm)	Baking Time (min)	Oven Temperature (°C)
1	26.75	26.45	25.41
2	26.00	26.64	26.67
3	26.14	25.81	26.81
Delta	0.75	0.83	1.40
Rank	3	2	1

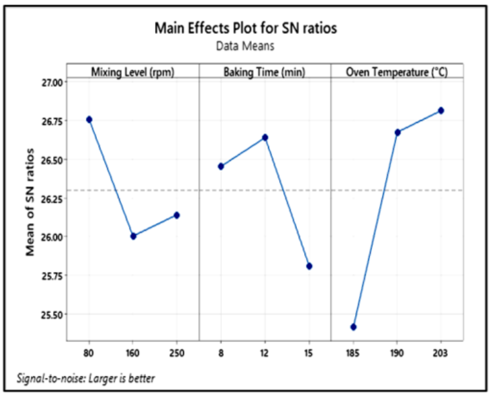

Figure 10. The ratio of S/N main effects plot and response table.

The mixing level's tendency is less important than other elements, according to this graph. From low to medium (80 rpm to 160 rpm) mixing settings, the S/N ratio has declined minimally, but for high (250 rpm) mixing settings, the S/N ratio gradually increased and approached the mean line. The graph pattern for baking time begins to rise gradually between 8 and 12 minutes. Between 12 and 15 minutes, the S/N ratio value declines progressively and reaches the S/N ratio value's minimum. The S/N ratio oven temperature is elevated between 185°C and 190°C until it reaches its maximum. After that, the baking temperature is slightly declined from 190°C to 203°C. Regarding Figure 10, baking time is the main component influencing the macarons production process's output quality compared to the others. Baking time is the most important control variable.

Figure 10 also displays three levels of setup: the average ratio of S/N values for every variable and the effect of every main effect on the ratio of S/N. At levels 1, 2, and 3, the S/N ratio mean for percentage mixing levels is 26.75, 26.00, and 26.14, respectively. Because it correlates to the largest average ratio of S/N, mixing level at level 1 seems like a better option. The S/N mean of the baking time ratio is 26.45, 26.64, and 25.81 at level 1, level 2, and level 3, respectively. When it comes to baking time, the S/N ratio shows that level 2 is preferable compared to levels 1 and 3. The most acceptable option is at level 2, which has the greatest average ratio of S/N. The level with the largest S/N ratio will be picked, just as it is with the S/N ratio of the oven temperature. The best option is level 3, with an S/N ratio of 26.81. According to the outcome of the analysis, the best characteristics for improving the quality of macarons product are the low-level setting of mixing at 80 rpm, 12 minutes of baking time, and 203°C of the oven temperature.

The means graph for the macarons production experiment is shown in Figure 11. In general, the largest ratio of S/N, the greater the quality. Figure 11 illustrates the appropriate settings for each control component to produce the best macarons product. Regarding Figure 11, the tendency of the mixing level is less important than the other variables:

Response Table for Means

Level	Mixing Level (rpm)	Baking Time (min)	Oven Temperature (°C)
1	21.78	21.04	18.80
2	20.25	21.50	21.56
3	20.28	19.77	21.95
Delta	1.52	1.73	3.15
Rank	3	2	1

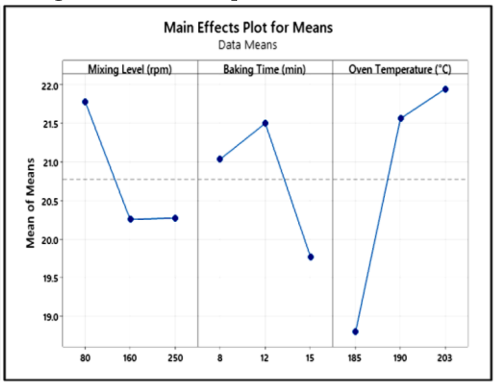

Figure 11. Means response table and main effects plot.

From low to medium (80 rpm to 160 rpm), the mean declines slightly but then gradually increases as it approaches the high's average line (250 rpm) type of mixing setup. The chart pattern for baking time begins to climb moderately between 8 and 12 minutes of baking time. By reaching the minimal value of the S/N ratio, the mean value between 12 and 15 minutes is drastically declined. Between 185°C and 190°C, the mean for oven temperature drastically climbed and then slowly increased between 190°C and 203°C. According to Figure 11, the baking oven is the most important factor affecting the macarons production process output quality.

Figure 11 also depicts the average mean values for every variable at three different levels and the influence of each main effect on the experiment's mean. The mean mixing level values for level 1, level 2, and level 3 are 18.80, 21.56, and 21.95, respectively. The mean of mixing level 1 appears to be the best option because it matches the largest average mean. At level 1, level 2, and level 3, the average baking time is 21.04, 21.50, and 19.77, respectively. This suggests that the parameter at level 2 is preferable for the baking time. As before, the highest mean level will be chosen as the best option for oven temperature, which in this case is 21.95. Based on the results, the low-level mixing at 80 rpm, 12 minutes of baking time, and 203°C of oven temperature are ideal for macarons production.

Since the range of ratio-variance due to a change in the level setting is equal to the maximum-minimum value, the bigger the range, the stronger the control factor's impact on quality. The outcome results demonstrate that the oven temperature has the highest rating and substantially affects the macaron's product quality. As a result, the baking time and mixing level are ranked second and third, respectively, and have relatively minor effects. Since this case study aims to optimize the macarons product process, maximal values are required to reduce variability. To achieve the best results, the oven temperature should be set at 203°C, followed by 80 rpm of mixing level and 12 minutes of baking time.

Analysis of Variance (ANOVA)

The ANOVA aims to determine which variable has the most impact on the quality of the macarons. The results are utilized to determine which factors are the most essential in terms of quality. As a result, the critical parameters highlighted must be carefully checked throughout the process to ensure a consistently high-quality macarons product. The ANOVA analysis is carried out by identifying the sources of variance in the left-hand column, which are the experimental factors. The label in an ANOVA analysis is described in Table 13, 14, and 15 below:

Table 13. Label of ANOVA analysis.

Label	Explanation
DF	This value indicates the factor's degree of freedom.
Seq SS	The squared deviation of a random variable from the mean is the sum of squares.
Adj MS	The sum of squares is divided by the number of degrees of freedom relating to the impact of the variables to get the mean square.
F	Measure the impact of each variable or relationship to the error using the conventional Fisher test for significance.
P	The % contribution of each variable is shown.

Table 14. Variance analysis ratio of S/N:

Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Mixing Level (rpm)	2	0.9628	0.9628	0.4814	0.35	0.742
Baking Time (min)	2	1.1369	1.1369	0.5684	0.41	0.709
Oven Temperature (°C)	2	3.5613	3.5613	1.7806	1.29	0.437
Residual Error	2	2.7662	2.7662	1.3831		
Total	8	8.4271				

Table 15. Variance analysis for means.

Analysis of Variance for Means

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Mixing Level (rpm)	2	4.577	4.577	2.288	0.34	0.745
Baking Time (min)	2	4.812	4.812	2.406	0.36	0.736
Oven Temperature (°C)	2	17.733	17.733	8.867	1.32	0.430
Residual Error	2	13.389	13.389	6.694		
Total	8	40.511				

Control Stage

The control stage described in this study is a form of recommendation to continue the project that has been carried out so that it can help control in a better direction. After the process has been improved in the previous stage, monitoring the quality of the product generated using the process's most recent sigma value is still required. The control stage will be carried out on the improvements that have been made using tools such as check sheets, quality reports, control charts, and documentation will be carried out. The bakers can use check sheet documentation to keep track of macarons product defects in each area of their operation. Quality reports are created to track the quality of macarons products by evaluating all types of defects that occur as well as the number of productions every shift. Statistical quality control can be performed by using a P chart, which is created by computing the percentage of defects found on the check sheet. Documentation is required to produce a new standard as part of the implementation process. This is an attempt to avoid a new system's tendency to revert to the old system's or work pattern.

ABC Company should not overlook the human factors that contributed to the macarons product's production error. The bakers should adhere to the work standard under any circumstances since human errors might affect the quality of the macarons product. The control stage is also included in the ISO 9001 quality management system. ABC Company can make Six Sigma part of its quality management system and significantly improve the efficacy and efficiency of the Six Sigma approach by adding typical Six Sigma requirements to the ISO 9001 internal audit questionnaires.

THE FRAMEWORK FOR MERGING SIX SIGMA WITH QUALITY MANAGEMENT SYSTEM (QMS) OF ISO 9001

In this case study, the integration of the ISO 9001 quality management system with Six Sigma emphasized "Measurement, Analysis, and Improvement" because both shared a continuous improvement strategy. The ISO process framework describes the need for continuous improvement and provides a comprehensive strategy for continuously improving to fulfill customer satisfaction. ISO requires a systematic and scientific approach to continuous improvements, such as Six Sigma. A Six Sigma approach is one of the most effective ways to increase the company's performance effectively. Figure 12 below illustrates the framework for merging Six Sigma with the Quality Management System (QMS) of ISO 9001:

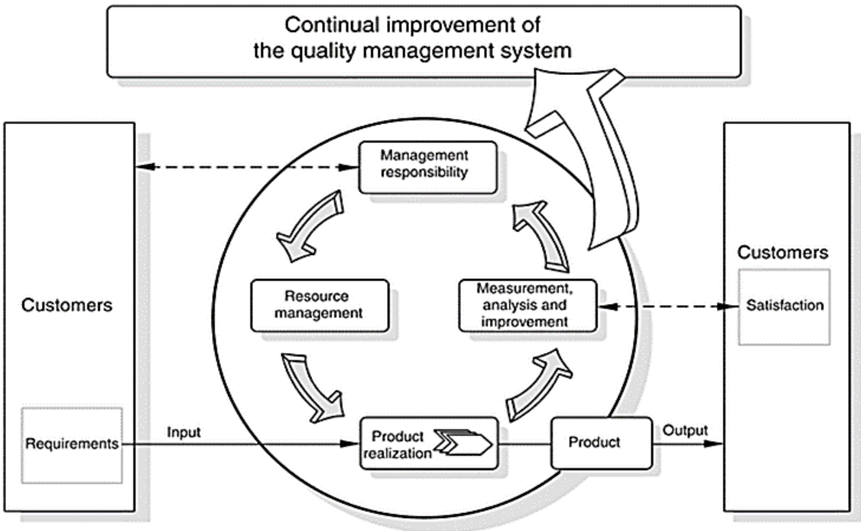

Figure 12. The framework for integrating Six Sigma and the Quality Management System (QMS).

Integration of ISO 9001 and Six Sigma can significantly increase the quality management system's credibility while also ensuring the Six Sigma initiative's long-term viability. The actual benefit of ISO 9001 can only be realized if businesses implement effective procedures that lead to quality improvements inside the company. Furthermore, the Six Sigma business improvement methods should be part of a quality management system that is always evolving. Six Sigma tools may describe a problem, measure the processes, evaluate the results, and improve the processes. Then ISO 9001 can be used to control and continuously improve these processes. The Quality Management System enables the company to keep the Six Sigma advantages going. Integrating Six Sigma with ISO 9001 assists the company in ensuring that there is no reversion to old processes following Six Sigma adoption. The company that benefits from Six Sigma frequently overlooks the need to develop a quality system, which is essential for continuously improving quality while minimizing nonconformities. The company can only maintain quality gains if they utilize a systems-based strategy. Both ISO 9001 and Six Sigma lead to increased performance and customer satisfaction. They work flawlessly together to create much greater long-term outcomes than if they were adopted separately.

IMPLICATION AND CONCLUSION CONCLUSION

The Sigma value in this case study resulted in a quality level of 2.50 for macarons product, with a total number of defects; 165000 DPMO from eight characteristics of CTQ. Cracked macarons (53.7%), hollow (16.3%), and no feet (16.1%) are the most common types of defects. Problem-solving will prioritize the three types of defects. Most of the defects that occur are caused by method and machine factors. The mixture level, baking time, and oven temperature are indicated as crucial aspects that impact the quality of the macarons production process. The analysis utilizing Taguchi's approach reveals that the best outcome is obtained when the process's parameters are set to low-level mixing of 80 rpm, 12 minutes of baking time, and 203°C of oven temperature. According to this optimal procedure of regulated parameter adjustment, the oven temperature is the most important aspect.

Assimilation of a Six Sigma with current management systems, especially with a quality management system, has long been acknowledged as a vital feature of a company's Six Sigma adoption. Furthermore, integrating Six Sigma with the ISO 9001 standard has reciprocal benefits. ABC Company's probability of getting closer to a high-quality product will be substantially higher when the main factors are controlled within the processes. Six Sigma approach provides ABC Company with more competence in the end product's quality. This is certainly relevant when a company's public image is so vital to customers. ABC Company will be able to cut the waste costs and the defect rate by employing Six Sigma with Quality Management System ISO 9001 in the macarons production process.

LIMITATIONS AND RECOMMENDATIONS

Regardless of the benefits indicated, there are some possible drawbacks to merging Six Sigma with an ISO 9001 Quality Management System. QMS ISO 9001 is sometimes chastised for having too many procedural formalities, which adds further limits to the efficient deployment of Six Sigma initiatives. Since the standard's version 2000 was published, QMS has become easier and more valuable for businesses; nevertheless, efforts must still be taken to reduce the usage of unneeded documentation and records while maintaining QMS processes and procedures uncomplicated. Six Sigma is frequently associated with a continuous improvement initiative that necessitates the use of numerous complex statistical tools, so people involved in the QMS ISO 9001 may be skeptical about their role within the Six Sigma program and the program's practical usefulness to the organization. Six Sigma should be recognized as a management strategy that includes all levels of the organization to assist in overcoming this possible difficulty. Six Sigma and QMS ISO 9001 may be seen as separate efforts, and the connections between them may be unclear to staff. This possible constraint can be solved by recording the links between Six Sigma and QMS ISO 9001 clauses and subclauses.

Integrating Six Sigma with the ISO 9001 Quality Management System standard is a new trend that many industrial organizations, particularly food industry companies, have adopted. However, the efficiency of these two integrations is still being debated. This case study suggests some future research on developing an instrument to quantify the efficacy of the integration of Six Sigma with the ISO 9001 Quality Management System. This future research is essential because the company requires knowledge on measurement instruments of the integration of Six Sigma with QMS ISO 9001 implementation effectiveness for measuring and improving their QMS and their company's production operations.

REFERENCES

Aday, S., & Aday, M. S. (2020). Impact of COVID-19 on the food supply chain. In *Food Quality and Safety* (Vol. 4, Issue 4, pp. 167–180). Oxford University Press. https://doi.org/10.1093/fqsafe/fyaa024

Admin. (2020, December 28). *Six Sigma Tools: DPU, DPMO, PPM and RTY*. Six Sigma Daily.

Alldredge, K., Henrich, J., Lal, S., & Verma, V. (2021). *COVID-19's impact on demand and costs in the CPG industry*. McKinsey & Company. https://www.mckinsey.com/industries/consumer-packaged-goods/our-insights/covid-19s-impact-on-demand-and-costs-in-the-cpg-industry

Anupama, P. (2017). *Adoption of Six Sigma DMAICto reduce cost of poor quality*.

ASQ. (2021a). *What is ISO 9001:2015? Quality Management System*. https://asq.org/quality-resources/iso-9001

ASQ. (2021b). *What is Quality Management System? (QMS)*. American Society for Quality. https://asq.org/quality-resources/quality-management-system

Chitrakar, B., Zhang, M., & Bhandari, B. (2021). Improvement strategies of food supply chain through novel food processing technologies during COVID-19 pandemic. In *Food Control* (Vol. 125). Elsevier Ltd. https://doi.org/10.1016/j.foodcont.2021.108010

Conway, J. (2021). *Impact of the coronavirus pandemic on the global FMCG market - Statistics & Facts*. Statista. https://www.statista.com/topics/6248/covid-19-impact-on-the-fmcg-market-worldwide/#dossierKeyfigures

Costa, L. B. M., Godinho Filho, M., Fredendall, L. D., & Gómez Paredes, F. J. (2018). Lean, six sigma and lean six sigma in the food industry: A systematic literature review. *Trends in Food Science & Technology*, *82*, 122–133. https://doi.org/https://doi.org/10.1016/j.tifs.2018.10.002

Davis, D., & John, P. (2018). Application of Taguchi-Based Design of Experiments for Industrial Chemical Processes. *Application of Taguchi-Based Design of Experiments for Industrial Chemical Processes*. https://www.intechopen.com/chapters/56460

Fraley, S., Oom, M., Terrien, B., & Zalewski, J. (2021, December 4). *Design of Experiments via Taguchi Methods - Orthogonal Arrays*. The LibreTexts.

Fremaux, A. (2021). *Impact of the COVID-19 crisis on European bakery markets*. Bakery, Biscuit,Pasta (BBM). https://www.magazinebbm.com/english/impact-of-the-covid-19-crisis-on-european-bakery-markets/.html

Girija. (2020, June 13). *Walmart Case Study: Lean Six Sigma Implementation in 2021*. Henry Harvin Education.

Kenton, W. (2021, September 27). *Taguchi Method of Quality Control*. Investopedia. https://www.investopedia.com/terms/t/taguchi-method-of-quality-control.asp

Kumar, V., Verma, P., & Muthukumaar, V. (2018). The performances of process capability indices in the Six-Sigma competitiveness levels. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, *2018-March*(June), 1945–1951.

Lemke, J., Kijewska, K., Iwan, S., & Dudek, T. (2021). Six Sigma in urban logistics management — A case study. *Sustainability (Switzerland)*, *13*(8). https://doi.org/10.3390/su13084302

Liu, Y. C., Kuo, R. L., & Shih, S. R. (2020). COVID-19: The first documented coronavirus pandemic in history. In *Biomedical Journal* (Vol. 43, Issue 4, pp. 328–333). Elsevier B.V. https://doi.org/10.1016/j.bj.2020.04.007

Marques, P., Requeijo, J., Saraiva, P., & Frazao-Guerreiro, F. (2013). Integrating six sigma with iso 9001. *International Journal of Lean Six Sigma*, *4*(1), 36–59. https://doi.org/10.1108/20401461311310508

Nikoli, K. (2018). Lean Six Sigma in Food Industry. In *International Journal of Basic & Applied Sciences IJBAS-IJENS* (Vol. 13, Issue 06).

Omoush, M. M. (2020). Lean Six Sigma Effect On The Quality of The Products In Jordanian: The Moderating Role f The Manufacturing Processs. *International Review of Management and Marketing*, *10*(6), 1–12. https://doi.org/10.32479/irmm.10680

Purwoharsojo, P., Syaharuddin, S., & Sampeliling, A. (2020). FMEA Approach of Lean Six Sigma Implementation: Estimating the Value of COPQ Syaharuddin Syaharuddin Universitas Mulawarman FMEA Approach of Lean Six Sixma Implementation: Estimating the Value of COPQ. *Article in International Journal of Psychosocial Rehabilitation*, *24*, 2020. https://doi.org/10.37200/IJPR/V24I3/PR2021160

Salazar, F. W., Tigre, F. G., Tubón-Núñez, E. E., Carrillo, S., & Buele, J. (2019). Implementation of the Quality Management System (ISO 9001: 2015) in the Bodywork Industry. *Journal of Information Systems Engineering & Management*, *4*(2). https://doi.org/10.29333/jisem/5890

Sarkar, S. A., Mukhopadhyay, A. R., & Ghosh, S. K. (2017). Root cause analysis, Lean Six Sigma and test of hypothesis. *TQM Journal*, *25*(2), 170–185. https://doi.org/10.1108/17542731311299609

Sumaedi, S., & Yarmen, M. (2015). The Effectiveness of ISO 9001 Implementation in Food Manufacturing Companies: A Proposed Measurement Instrument. *Procedia Food Science*, *3*, 436–444. https://doi.org/10.1016/j.profoo.2015.01.048

Tampubolon, S., & Purba, H. H. (2021). Lean six sigma implementation, a systematic literature review. In *International Journal of Production Management and Engineering* (Vol. 9, Issue 2, pp. 125–139). Universidad Politecnica de Valencia. https://doi.org/10.4995/IJPME.2021.14561

Utami, M. W. D., Ma'aram, A., & Hisjam, M. (2021). Six Sigma Implementation in Production Process in Electronic Company Malaysia. *IOP Conference Series: Materials Science and Engineering*, *1096*(1), 012012. https://doi.org/10.1088/1757-899x/1096/1/012012

CONFLICT OF INTEREST

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