Factors Influencing Product Quality in Milk Processing Industry

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Abstract

The production of liquid milk has many defects which result in the loss of the opportunity to gain benefits that can be obtained if the quality of the product complies with the prescribed standards. This study aims to determine what factors influence the quality of milk bottled products in the milk processing industry in Jakarta. Quality Function Deployment (QFD) is used to find out what factors influence the quality and how to achieve these factors. Failure Mode and Effect Analysis (FMEA) is used to determine the risk of potential failure of factors that achieve high credence at the QFD stage. The results of the data processing show that workers/operators, production equipment, and production processes have the highest importance in influencing product quality in the milk processing industry. The results of the data processing also show that the filling and sterilization process have the highest risk of causing defects with Risk Priority Number (RPN) above 100. Dented (body) receives an RPN of 240, channeling receives an RPN of 140, dented (skewed) receives an RPN of 128, and scratch receives an RPN of 120.

Keywords
Quality Management, Dairy Manufacturing Industry, QFD, FMEA

1. Introduction

The Processing Industry in Indonesia accounts for 19.83% and is the largest contributor to Indonesia's GDP in the second quarter of 2018. The Food and Beverage Industry contributes up to 31.8% of the processing industry's GDP. Therefore, the Food and Beverage Industry is still a mainstay sector for Indonesia's economic growth contributors. The growth is driven by the increase of the civil incomes and the growing of the middle-class population accompanied by their tendency towards the public consumption pattern which leads to consuming ready-to-eat processed food products. In Government Regulations number 14 of 2015 which concerns the master plan for national industrial development, one of the basis sectors is the food industry. One of the priority subsectors in the food industry is the milk processing industry. This subsector is a strategic industry group and has bright prospects to be developed, it is indicated by the growth rate of domestic beverage industry which is able to rise by 8.41% in the first semester of 2018. The number of Milk Processing Industries in Indonesia keeps increasing every year, and in 2018 the amount reaches 36 units.

There are three types of dairy products that are the leading intake of Indonesian people, namely sweetened condensed milk, powdered milk, and factory liquid milk with a percentage of 50%, 30%, and 20% respectively. The volume of milk consumption in Indonesia is still dominated by sweetened condensed milk by half. According to statistic of food consumption by Ministry of Agriculture, although liquid milk has the lowest market share, for the past five years, ready-to-drink liquid milk has the fastest growth rate at 25% per year, followed by sweetened condensed milk which grows 11% per year, while powdered milk only grows 4% per year. With the large growth rate of consumption of ready-to-drink liquid milk in Indonesia and the increasing number of competitors entering the market, milk processing companies must be able to produce high quality and nutritious dairy products.

One of many milk processing companies in Jakarta has an average amount of liquid milk production of 66,590 liters per day. Based on historical data, the average number of products that do not meet established quality standard is 1,940 cartons out of 320,699 cartons produced or equivalent to 0.62% per month, even though the company determines

the maximum defect limit is 0.2%. The product is categorized as a defect product that is not worth selling and must be destroyed.

In addition to cause losses to the company, rejected product wastes also need to be destroyed. The destruction itself requires additional costs because it uses the services of a third party. On the basis of the above background, it is necessary to analyze factors which cause the defects. Therefore, this study aims to determine what factors influence the quality of the product in the company.

2. Literature Review

2.1 Quality Management

The term 'quality' has different meanings due to differences in how experts define it. Juran defines Quality as product features that meet customer needs and make customers satisfied. It also means freedom from shortcomings, namely freedom from mistakes that need rework or that result in field failure, customer dissatisfaction, customer claims, etc. According to Deming, quality has many different criteria and keeps changing depending on who the interpreter is. Therefore, it is important to measure consumer preferences and remeasure continuously. Crosby interpreted the term quality briefly as conformity with the requirements or standards that have been set. In conclusion, 'quality' is defined as a dynamic state that is related to products, services, people, processes, and environments that meet or exceed consumer expectations and help produce superior values (Goetsch & Davis, 2016). Anything that does not meet the specified quality requirements will be categorized as a defect (Pande, Neuman, & Cavanagh, 2002).

2.2 GMP

Good Manufacturing Practice (GMP) is an aspect of quality assurance which ensures that the goods produced are consistently manufactured and controlled according to quality standards that go in accordance with the intended use and as required by product specifications. GMP is a requirement for all activities related to food production, manufacturing, and distribution. These principles must be applied at all stages of production for the distribution and retail sale of the final products through the procurement of raw materials and the manufacturing of products. The aim of GMP is to ensure that the food is consistent with those needs (Jarvis, 2014). GMP contains complete and detailed specifications of a product and everything that goes into its making, storing, and distribution; material management, resources, and preventive measures to ensure that specification requirements are met (Blanchfield, 2005).

2.3 QFD

Yoji Akao proposed QFD in 1970 as a tool to develop quality. QFD is a very significant technique to take the stakeholder needs into account. QFD changes the quality requirements for stakeholders or company customers, suppliers, and employees for quality characteristics. At present, QFD has been used extensively in various fields (Abdel-Basset, Manogaran, Mohamed, & Chilamkurti, 2018). The QFD framework is used to understand the requirements set by potential users (industry, product end users) (Eldermann, Siirde, & Gusca, 2017).

2.4 FMEA

FMEA has the ability to define, identify, and eliminate potential product failures from the process (Nooted & Tangjitsitcharoen, 2017). FMEA is an effective method and tool for analyzing procedures and risk assessment and is able to offer critical assistance for analysis and improvement in manufacturing processes (Zhao & Zhu, 2010). FMEA can help evaluate the product, the project, and the whole process itself. It can help eliminate defects that have occurred as well as those that may appear during production (Rekas, Kurek, Latos, & Milczanowska, 2014). FMEA can be used to identify potential causes to diminish and detect failures in a production process which are determined by factors that are Severity (S), Occurrence (O) and Detection (D). Risk Priority Number (RPN) can be obtained from multiplying the three factors (S x O x D) to determine potential failure effect. (Nooted & Tangjitsitcharoen, 2017).

A number of risk priority higher than 100 indicates that there's a potential failure and correction action should be performed. The highest RPN possible is 1000 (10 x 10 x 10) which means it has the greatest possible failure. From an RPN of 1000, 10% of that amount has statistical confidence of 90%. Control measures of each potential failure mode

and the RPN should be calculated to identify the corrective actions effect possibilities to be done in the process improvement (Ozilgen, 2012).

3. Methods

First, data collection is carried out by searching the (Quality Requirements) QR and (Technical Requirements) TR factors through literature studies. From the literature study conducted, there are 9 QR that affect product quality in the milk processing industry which can be seen in Table 1.

Table 1. Factors influencing product quality from the literature study

No.	Variable/QR	References
1	Worker/Operator	(Bargelis, Čikotienė, & Ramonas, 2014), (Doulatabadi & Yusof, 2014), (Nooted & Tangjitsitcharoen, 2017)
2	Working environment	(Bargelis et al., 2014), (Doulatabadi & Yusof, 2014), (Teh, Adebanjo, & Ahmed, 2014)
3	Production complexity	(Lombard, Waveren, & Chan, 2014), (Nooted & Tangjitsitcharoen, 2017)
4	Raw materials	(Bargelis et al., 2014)
5	Production facility	(Bargelis et al., 2014), (Nooted & Tangjitsitcharoen, 2017)
6	Production tools	(Bargelis et al., 2014), (Nooted & Tangjitsitcharoen, 2017)
7	Production process	(Nooted & Tangjitsitcharoen, 2017), (Lombard et al., 2014)
8	Organization culture	(Lombard et al., 2014), (Doulatabadi & Yusof, 2014)
9	Labor management	(Teh et al., 2014), (Lombard et al., 2014)

Then the QR and TR obtained will be assessed by six experts. QR and TR factors that exceed the threshold will be used in this study. After the assessment is conducted, the average value for each variable and indicator will be calculated. Factors that have an average value smaller than 3.5 will be eliminated because they are considered out of synch with the conditions of the Milk Processing Industry in Indonesia. From the calculation, 7 QR and 24 TR are obtained and can be seen in Table 2.

Table 2. QR and TR obtained from the calculation

1. Worker/Operator
Washing hands with water and soap before making a contact with a product
Not touching a product with bare hands
Wearing production attire only inside the production room
Not inviting workers who indicate clinical symptoms
Applying workers' discipline
2. Working environment
The temperature of production and storage room
The humidity of production and storage room
Separating high-risk materials when safekeeping and handling
3. Production complexity
Production process design complexity
4. Raw materials
Choosing the compatible supplier
Testing the sample of the raw materials
5. Production facility
Smooth floor, not cracked, easy to clean
Not cracked/perforated wall
Sealed roof (not cracked/perforated) to prevent foreign material from falling into the production process
The production building must be safe from disturbance caused by animals (for example birds, pests, and other insects)
Each part of the building, including the outer part, must be maintained and in a clean and orderly condition

6. Production tools
Using hygienic tools
Cleaning the production tools/machinery in accordance with the applied quality system
Doing effective maintenance on the production machinery
Doing a regular calibration on the production tools and machinery
7. Production process
Production is carried out and supervised by competent individuals
Conducting a production process which goes accordingly with the specified procedure / written instructions
Conducting heating according to procedure / written instructions
Validating the process to optimize the quality and efficiency and ensuring the food safety

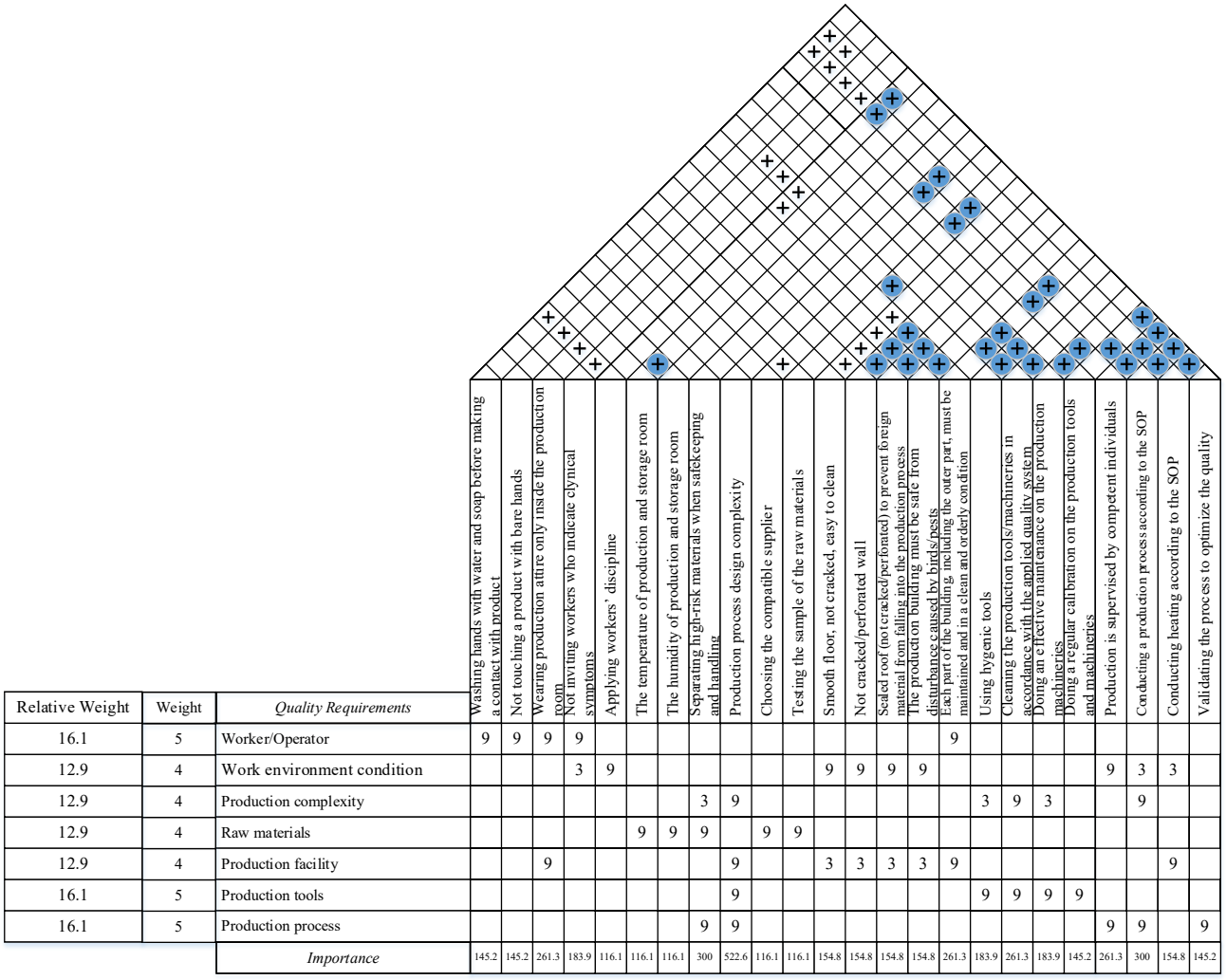
In this study, QFD is used to find Quality Requirements (QR), which is the factor that affects the quality and how to achieve these quality requirements. To determine the QR and TR that will be used in a QFD method, a literature study is carried out from previous studies regarding factors that affect quality, then these factors are tested for compatibility or validation by experts from the object of research, suitability assessment using geomean. The steps in preparing the QFD are determining Quality requirements, determining Technical requirements, constructing the matrix of the relationship between Quality requirements and Technical requirements, constructing internal dependencies between Technical requirements, and calculating the overall technical requirements priorities. The relationship matrix between QR and TR created with three numbers which are 9 (strong), 3 (moderate), 1 (weak), to represent the effect of TR on QR. The priorities of TR are calculated by multiplying the numbers on the matrix of the TR and QR relations with the relative weights of QR. The results of QFD are the highest weighting factors that will be used in the FMEA method.

A more in-depth analysis of main factors with the highest importance weight in QFD stage will be resumed using the FMEA method to determine the causes, impacts, and modes of failure that may occur from these factors and provide corrective actions to reduce the risk of failure. The steps for processing data using FMEA are as follows (Susanti, Dachyar, & Yadrifi, 2015):

a. Identify of Component Functions
b. Determine Potential Failures
c. Determine the Effects of Each Failure
d. Determine the Causes of Each Failure
e. Identify of Process Control
f. Look for Severity (S) Rating, Occurrence (O) Rating, and Detection Rating (D)
g. Calculate RPN (SxOxD)

4. Result and Discussion

Worker/operator, production process, and production tool are factors which have the most significant influence on quality based on the QFD stage. In addition, the complexity of the design of the production process (TR 3.2); the separation of high-risk materials during storage and handling (TR 2.4); and the conduct of the production process according to the procedure or written instruction (TR 7.3) are 3 TR with the highest relative importance weight which has a strong influence on the factors that affect quality. The full HOQ diagram can be seen in Figure 1.



Relative Weight	Weight	*Quality Requirements*	Washing hands with water and soap before making a contact with product	Not touching a product with bare hands	Wearing production attire only inside the production room	Not inviting workers who indicate clynical symptoms	Applying workers' discipline	The temperature of production and storage room	The humidity of production and storage room	Separating high-risk materials when safekeeping and handling	Production process design complexity	Choosing the compatible supplier	Testing the sample of the raw materials	Smooth floor, not cracked, easy to clean	Not cracked/perforated wall	Sealed roof (not cracked/perforated) to prevent foreign material from falling into the production process	The production building must be safe from disturbance caused by birds/pests	Each part of the building, including the outer part, must be maintained and in a clean and orderly condition	Using hygenic tools	Cleaning the production tools/machineries in accordance with the applied quality system	Doing an effective maintenance on the production machineries	Doing a regular calibration on the production tools and machineries	Production is supervised by competent individuals	Conducting a production process according to the SOP	Conducting heating according to the SOP	Validating the process to optimize the quality
16.1	5	Worker/Operator	9	9	9	9												9								
12.9	4	Work environment condition				3	9							9	9	9	9							9	3	3	
12.9	4	Production complexity								3	9								3	9	3				9		
12.9	4	Raw materials						9	9	9		9	9														
12.9	4	Production facility			9						9			3	3	3	3	9								9	
16.1	5	Production tools									9								9	9	9	9					
16.1	5	Production process								9	9													9	9		9
		Importance	145.2	145.2	261.3	183.9	116.1	116.1	116.1	300	522.6	116.1	116.1	154.8	154.8	154.8	154.8	261.3	183.9	261.3	183.9	145.2	261.3	300	154.8	145.2

Figures 1. The House of Quality

The results of further analysis of the three factors (QR) with FMEA show that the filling and sterilization process have the highest risk of causing defects with RPN above 100. Dented (body) has an RPN of 240, channeling has an RPN of 140, dented (skewed) has an RPN of 128, and dented (skewed) has an RPN of 120. The failure in form of the flat bottle has the highest severity (9), but occurrence frequency and current detection control have a very low rank, resulting in a small RPN. The full FMEA and the corrective action can be seen in Table 3 and Table 4.

Table 3. FMEA

Factor	Potential failure	Potential results of failure	S	Potential causes	O	Presents means of detection	D	RPN
Worker/ Operator	Physical contamination	Product Contaminated	7	Operator not wearing gloves	1	Laboratorium test	2	14
	Chemical contamination		8	The operator didn't wash their hand	1	Laboratorium test	2	16
Production equipment	Physical contamination	Product Contaminated	6	Contaminants from packaging material	1	Laboratorium test	2	12
	Chemical contamination		3	Metal contaminants from production equipment	1	Laboratorium test	2	6
	Physical contamination		5	Contaminants from raw material	1	Laboratorium test	2	10

Factor	Potential failure	Potential results of failure	S	Potential causes	O	Presents means of detection	D	RPN
Pouring/ Mixing Process	Physical contamination	Product Contaminated	5	Dust from the environment	1	Laboratorium test	2	10
	Biological contamination		6	Microorganism from the environment	1	Laboratorium test	2	12
	Chemical contamination		7	Detergent and/or disinfectant residue due to inadequate cleaning process	1	Laboratorium test	2	14
Filling Process	Censor failure	Volume is not suitable	3	Uncalibrate censor	2	Automatic rejector	3	18
	The seal is not tight	Channeling	7	Foamy product	4	Manual	5	140
	Folded foil	Wrinkled Foil	7	Improper foil rolls	1	Manual	3	28
	Microbiological contamination	Product contaminated	7	Improper cleaning process	1	Manual	6	42
Sterilization Process	Censor failure, layer	Dented (body)	8	Improper temperature	5	Manual	6	240
		Dented (skewed)	8	Improper pressure	4	Manual	4	128
	Unstable pressure	Flat bottle	9	Broken steam, less water	1	Manual	2	18
	Untight autoclave	Scratch	5	Filling machine scratch the foil	4	Manual	6	120
Labelling Process	Improper label	Improper label position	4	Product's position is too low or too high	4	Manual	4	64
		Folded label	4	Cutting machine failure	4	Manual	4	64
		Unvivid label	4	Label not printed properly	4	Manual	4	64
		Wrinkled label	4	Cutting machine failure	4	Manual	4	64
Coding Process	Improper code	No code	4	Operator's error	5	Manual	4	80
		Unvivid code	4	Printer's tint error	5	Manual	4	80
		Wrong code	4	Operator's error	5	Manual	4	80
Packing Process	Robot palletizer scratch the carton	Dented carton	3	System error	2	Manual	3	18
Storage	Microbiological contamination	Rotten product	8	Improper temperature and humidity	3	Manual	4	96

Table 4. The corrective action in FMEA

Factor	Potential failure	Potential results of failure	S	Potential causes	O	Presents means of detection	D	RPN	Corrective Action	S	O	D	RPN
Filling Process	Alumunium foil is not tight	Channeling	7	Foamy product	4	Manual	5	140	Prevent the product from foaming	6	2	5	60
Sterilization Process	Censor failure, layer	Dented (body)	8	Improper temperature	5	Manual	6	240	Control the temperature and replace the layer	5	4	4	80
	Unstable pressure	Dented (skewed)	8	Improper pressure	4	Manual	4	128	Control the pressure and replace the layer	7	3	4	84
		Scratch	5	Filling machine scratch the foil	4	Manual	6	120	Close autoclave tightly	5	3	6	90

QFD and FMEA have different frameworks, yet they complement each other's limitations, thus they can effectively guide quality control. QFD helps to understand and prioritize which factors are most important in influencing product quality, and FMEA is an effective way to help analyze the risks, causes, and effects of any quality failures that might occur. The customer in the QFD method in this study is the company itself.

In this study, experts consider that the factors of organizational culture and management of labor do not have a large influence on the quality of the products. This result is contrary to (Lombard et al., 2014) which stated that organizational culture and labor management are important factors that affect the quality of the products.

Based on the results of in-depth interviews with experts in companies who control liquid milk production, it is stated that, in other branch factories, there are differences in the tools used in the production process, namely baskets. Baskets that are used in Jakarta factories do not have barriers for each bottle, while in other factories the baskets have barriers for each bottle. The difference results in a number of different defects. For example, if one uses a basket without a partition, the dented products will be produced to a large degree because the products in the basket without the bulkhead will intersect with each other. In other words, there will be no limit, but the level of the scratch product is small. On the other hand, if one uses baskets with bulkheads, the products will not come into contact with each other so the damage to the dented category products is minimal. However, due to the bulkhead in the basket, the possibility of the product being shaken is very high, causing the product head in the form of aluminum foil scratched with the upper layer.

5. Conclusion

A reliable worker/operator (QR1), a good production process (QR6), and adequate production tools (QR7) are three main factors that influence product quality in the milk processing industry. The complexity of production process design (TR 3.2); separation of high-risk materials during storage and handling (TR 2.4); and conducting the production process according to the procedure or written instruction (TR 7.3) are 3 TR with the highest relative importance. The filling and sterilization process have the highest potential of causing defects with an RPN above 100. Dented (body) has an RPN of 240, channeling has an RPN of 140, the dented body has an RPN of 128, and dented (skewed) has an RPN of 120. Failure in form of a flat bottle gets the highest severity (9), but the ranking for the occurrence frequency and the current detection control is so low that the resulting RPN is small.

Based on the results of the above analysis, managerial advice and recommendations that goes accordingly with the current condition of the company and can be applied to reduce defects are by replacing the layer with the new one and analyzing the layer material currently used to see whether it is suitable for the existing requirements. Therefore, to suppress the number of dents, benchmarking can be done to other branch factories regarding the temperature used for the sterilization process in order to reduce the risk of overheating, resulting the bottle to deform from its initial form. In addition to improve the tools and methods used, it is also important to provide problem solving training for workers/operators to enhance their skill in taking action as well as increase their contribution in every job (production process) that is carried out, such as when there is temperature or pressure instability, workers/operators in the field must be able to take an action so that the damage is not too severe.

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