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Application of the Six Sigma Method to Improve the Quality of Cocoa Oil Industry Products in Southeast Sulawesi Province, Indonesia

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This research aims to control the quality of cocoa oil industry products through the application of the six sigma method. This research was carried out in the cocoa oil industry centre area in Southeast Sulawesi Province, which accommodates 3 (three) regions, namely; North Kolaka Regency, East Kolaka Regency, and Kolaka Regency. The population in this study were owners or managers of the cocoa oil industry, totaling 130 industries. The research sample used census techniques, namely; the entire population is used as a sample. Data collection techniques were carried out through interviews and direct observation at each industrial location during the cocoa oil production process. The analysis used in this research is Six Sigma analysis with the Define, Measure, Analysis, Improve, and Control (DMAIC) approach. The research results show that there is an average of 17.74% defective cocoa oil products for each production. In addition, the results of this study show that the types of defective cocoa oil products are smell mismatch (17.74%), color (3.71%), taste (7.60%), and water content (70.95%). The results of this research also provide information that the solution needed to control the quality of cocoa oil products is replacing production equipment and production support, establishing partnerships with cocoa bean suppliers from more profitable sources, improving the soft and hard skills of the workforce as well as mentoring, providing machines. more adequate packaging, as well as the use of ethanol solution in the extraction process.
Keywords: Six Sigma, DMAIC, quality, cocoa oil industries, cocoa oil industrial centre area.

INTRODUCTION

The development of the cocoa oil industry in the cocoa oil industry center area in Southeast Sulawesi is directed at increasing added value and sustainable competitiveness. This is supported by the connection of cocoa oil production in the cocoa oil industrial center area in Southeast Sulawesi with the large cocoa oil industry, namely; PT. Mars Indonesia is located in East Luwu Regency, South Sulawesi (Zaid *et al*., 2017; Zaid *et al*., 2018). However, after the COVID-19 pandemic, the supply of cocoa oil from the cocoa oil industrial center area went to PT. Mars Indonesia is starting to decrease. This is due to a decline in the quality of cocoa oil produced by industrial players in the cocoa oil industry center area in Southeast Sulawesi. This condition causes a decrease in the volume of cocoa oil production in the central area Zaid *et al.* (2023) found that the factors determining the quality of cocoa oil in the cocoa oil industry centre area in Southeast Sulawesi Province using the Analytical Hierarchy Process (AHP) were predominantly determined by the quality of raw materials (cocoa beam), use of production supporting materials, as well as equipment used in the production process. Based on the results of this research, the current research aims to conduct a study on cocoa oil quality control in the cocoa oil industry centre area in Southeast Sulawesi. This quality control study will use the Six Sigma method with the aim of producing a comprehensive and sustainable cocoa oil quality control method. It is hoped that the results of this study will be able to improve the quality of the cocoa oil produced so that it can trigger an increase in the production volume and supply of cocoa oil from the cocoa oil industrial centre area in Southeast Sulawesi to PT. Mars Indonesia. The originality of this research is to control the quality of cocoa oil products by applying the Six Sigma method, where this application has never been carried out in previous research. This research will be useful in improving the quality of cocoa oil products in the cocoa oil industry center area in Southeast Sulawesi so as to increase the competitiveness and added value of the industry. Besides that, it is hoped that this research will be useful for the community in improving the economic level of the

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community by increasing local workforce absorption which can have an impact on reducing the number of unemployed. Apart from that, it is also hoped that this research can provide input for the government in determining policies for developing the capacity of the cocoa oil industry in Southeast Sulawesi Province. Quality control is generally defined asintegrated activities within the company to maintain and maintain the quality of the products produced so that they can run well and according to established standards (Walujo *et al*., 2020; Umam and Kalista, 2021). Quality control is seen as an effort to maintain the quality of the products produced so that they comply with product specifications that have been determined based on company policy or based on market demands (Umam and Kalista, 2021; Hardiyanti *et al*., 2021). Quality control aims to ensure that the products produced comply with established quality standards (Hardiyanti *et al*., 2021). Apart from that, quality control also aims to reduce inspection costs, design costs and process costs. Quality control also aims to increase production cost efficiency (Walujo *et al*., 2020; Hashari, 2021; Hardiyanti *et al*., 2021). Quality control aims to prevent deviations, whether in materials, labor, time or quality of finished goods, as well as to correct errors that have occurred before, during and after the production process (Walujo *et al*., 2020; Hardiyanti *et al*., 2021). Quality control is generally carried out using three approaches, namely as follows: (a) Input Approach: Quality control based on the input approach is control by setting very strict standards for raw material specifications that are carefully checked, the workforce used is strictly selected, and production facilities or equipment are carefully selected (Walujo *et al*., 2020; Umam and Kalista, 2021 ; Hashari, 2021), (b) Process Approach: This approach is carried out through strict control of the production process standards carried out in order to minimize deviations and any damage to production equipment is immediately repaired (Walujo *et al*., 2020; Umam and Kalista, 2021; Hashari, 2021), (c) Outward Approach: This approach is carried out by looking at the conformity of the final product with orders or standards that have been set, namely by viewing and examining product samples (Walujo *et al*., 2020; Umam and Kalista, 2021; Hashari, 2021). Six sigma is a method of improving quality and reducing failure rates (Soemohadiwidjoyo, 2017; Botutihe *et al*., 2020; Fitriani and Putry, 2020). Six sigma was created to eliminate waste, reduce costs due to poor quality and improve the effectiveness of all operational activities with a target of perfection (Soemohadiwidjoyo, 2017). The basic principle of Six Sigma is product improvement by making improvements to the process so that the process produces a perfect product. The Six Sigma approach is used to identify matters relating to error handling and product rework that will cost money, time, reduce opportunities to earn income, reduce opportunities to increase income (Soemohadiwidjoyo, 2017; Fitriani and Putry, 2020; Qayyum *et al*., 2021). The six sigma method commonly used in quality control is: Define, Measure, Analyze, Improve, Control (DMAIC) (Soemohadiwidjoyo, 2017; Botutihe *et al*., 2020; Qayyum *et al*., 2021; Firmanto *et al*., 2021). Define: formally define process improvement goals that are consistent with customer requests or needs and company strategy, Measure: measuring current process performance (baseline measurements) so that it can be compared with set targets. Carry out process mapping and collect data relating to key performance indicators, Analyze: analyze the cause-and-effect relationships of various factors studied to determine the dominant factors that need to be controlled, Improve: optimize the process using analyzes such as design of experiments (DOE), etc., to determine and control the optimum conditions of the process, and Control: carry out control over processes continuously to improve process capabilities towards Six Sigma (Soemohadiwidjoyo, 2017; Costa *et al*., 2021; Gupta *et al*., 2020).

MATERIALS AND METHODS

This research will be carried out in the cocoa oil industry center area in Southeast Sulawesi, Indonesia; namely in East Kolaka Regency, Kolaka Regency and North Kolaka Regency. This research adopted data sourced from respondents from 130 industries, with distribution; 97 industries located in North Kolaka Regency; 24 industries located in East Kolaka Regency; and 9 industries in Kolaka Regency. Data collection was carried out using interview techniques and direct observation when the industry carried out the cocoa oil production process. The analysis used in this research is Six Sigma analysis with the approach of define, measure, analyze, improve, and control, with a description of the stages as follows:

a. ***Define*****:** is a stage that aims to define the problem of quality degradation faced by the cocoa oil industry. At this stage, the types of defects in cocoa oil products are identified. In carrying out this identification, check sheet analysis is used.

b. ***Measure*****:** is a stage that aims to map and measure the types of defects in cocoa oil products that have been identified. In carrying out these measurements, p-chart analysis was used.

c. ***Analysis*****:** is a stage aimed at finding out important problems that cause defects in cocoa oil products. At this stage, the analysis used is the Pareto diagram and Fishbein diagram.

d. ***Improve*****:** is a stage that aims to identify improvement efforts that can be made to repair defective products in order to improve the quality of cocoa oil products. At this stage the analysis used is focus group discussion (FGD).

e. ***Control*****:** is a stage that aims to supervise and control efforts to overcome defects in cocoa oil products that have been produced at the improve stage. At this stage, the analysis used is quality control group analysis.

RESULTS AND DISCUSSION

***Define*:** Quality control analysis using the six sigma method begins by defining defect problems in cocoa oil products using check sheet analysis. Check sheets are used for sorting data into different categories such as causes, problems and so on. Data that has been sorted in detail is collected using check sheets, while also facilitating further processing to provide an overview of the factors that are relevant to the problem being faced. The results of the check sheet calculation for the quality of cocoa oil products show that from a total of 130 industries that carry out the cocoa oil production process with the same amount of raw material for each industry, namely 10 kg of cocoa beans (assuming the production equipment used is the same), the total oil production in 130 industries it was 255,935 ml of cocoa oil, with the average production amount for each industry being 1,969 ml of cocoa oil. Of this amount, the total defective product was 7,146 ml of cocoa oil or 2.792%. When compared with the standard tolerance value for defective products for each production process, which is 1 to 1.5%, it can be concluded that the average cocoa oil production process in the cocoa oil industrial center area in Southeast Sulawesi is considered inefficient. Based on the proportion of products that are defective or do not meet cocoa oil quality standards of 7,146 ml, there are 1,268 ml or 17.74% who experience defective products due to smell incompatibility, as many as 534 ml or 7.60% are experienced product defects due to taste discrepancies, 265 ml or 3.71% due to color discrepancies, and 5,065 ml or 70.88% due to water content discrepancies. This indicates that the occurrence of defective cocoa oil products produced in the cocoa oil industrial center area in Southeast Sulawesi is predominantly caused by a mismatch in water content. This concludes that the production process carried out by the cocoa oil industry must be more focused on meeting cocoa oil moisture content standards (Soemohadiwidjoyo, 2017; Costa *et al*., 2021; Gupta *et al*., 2020).

***Measure*:** The second stage in controlling the quality of cocoa oil products using the six sigma method is measure. This stage is carried outmapping and measuring the types of defects in cocoa oil products that have been identified. In carrying out these measurements, p-chart analysis was used. P-Chart is an attribute control chart that is used to control the defective product portion of production results. The P-Chart is used to determine whether the product defects produced are still within the required limits or not (Soemohadiwidjoyo, 2017; Costa *et al*., 2021; Gupta *et al*., 2020). The results of the P-Chart calculation show that the calculation results show that the Ṕ value is 0.02792 and the 1-Ṕ value is 0.97208, and the CL value is 0.0279. The results of the P-Chart calculation show that there are several industrial samples that produce cocoa oil with the proportion of defective products above the highest threshold. These production samples are in industrial samples 1-6, 16-21, 56-61, 66-71, and 116-126. If we look at the distribution of industrial samples, the cocoa oil industry in the North Kolaka Regency area is the industrial sample that experiences the most product defects above the maximum threshold. The P-Chart diagram for calculating defective cocoa oil products in the cocoa oil industry center area in Southeast Sulawesi can be seen in Figure 1.

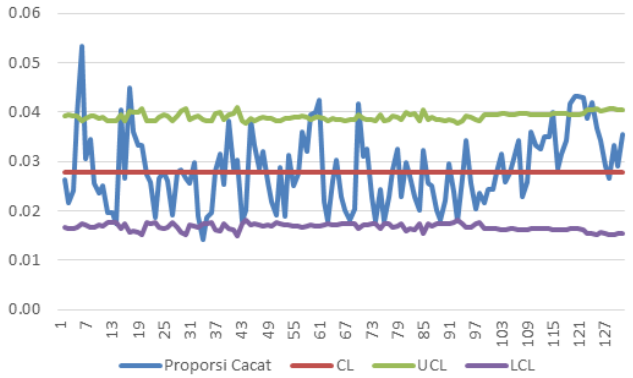

Figure 1. P-chart diagram cocoa oil defective products.

After obtaining the results of the P-Chart analysis for all defective products produced by industries in the cocoa oil industrial center area of Southeast Sulawesi, then a P-Chart analysis will be carried out to find out the description of defective products for each type of defective product, namely; smell, taste, color and water content (Soemohadiwidjoyo, 2017; Costa *et al*., 2021; Gupta *et al*., 2020).

***a. Smell*:** The calculation results P-Chart for defective products caused by smell incompatibility in the cocoa oil industry in the cocoa oil center area in Southeast Sulawesi, it shows that from the calculation results obtained a Ṕ value of 0.00495 and a 1-Ṕ value of 0.99505, and a CL value of 0.0050.

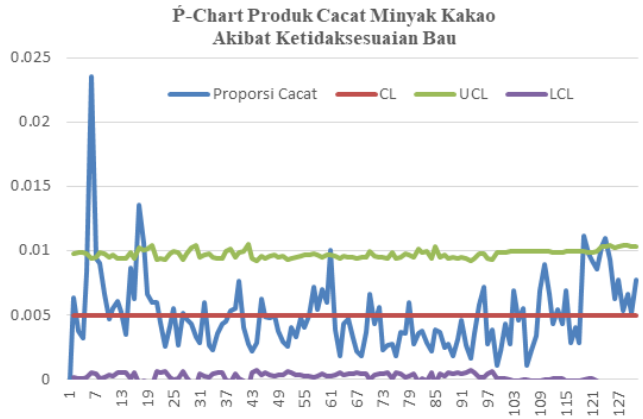

Figure 2. P-chart diagramcocoa oil defective products consequences of smell incompatibility.

The results of the P-Chart calculation show that there are several industrial samples that produce cocoa oil with the

proportion of defective products due to smell incompatibility that is above the highest threshold. These production samples are in industrial samples 6-7, 16-21, 61, 121, and 125-126. If we look at the distribution of industrial samples, the cocoa oil industry in the North Kolaka Regency and Kolaka Regency areas is the industrial sample that experiences the most product defects caused by smell mismatches above the maximum threshold. P-Chart diagram for calculating defective cocoa oil products due to smell incompatibility in the cocoa oil industrial center area in Southeast Sulawesi, can be seen in Figure 52.

***b. Flavor*:** The calculation results P-Chart for defective products caused by taste incompatibility in the cocoa oil industry in the cocoa oil center area in Southeast Sulawesi, it shows that from the calculation results obtained a Ṕ value of 0.00212 and a 1-Ṕ value of 0.99788, and a CL value of 0.0021. The results of the P-Chart calculation show that there are several industrial samples that produce cocoa oil with the proportion of defective products due to taste incompatibility that is above the highest threshold. This production sample is in industrial samples 60-61, and 120 - 126. If seen from the distribution of industrial samples, the cocoa oil industry in the North Kolaka Regency and Kolaka Regency areas is the industrial sample that experiences the most product defects caused by non-conformance. taste above the maximum threshold. The P-Chart diagram for calculating defective cocoa oil products due to taste incompatibility in the cocoa oil industrial center area in Southeast Sulawesi can be seen in Figure 3.

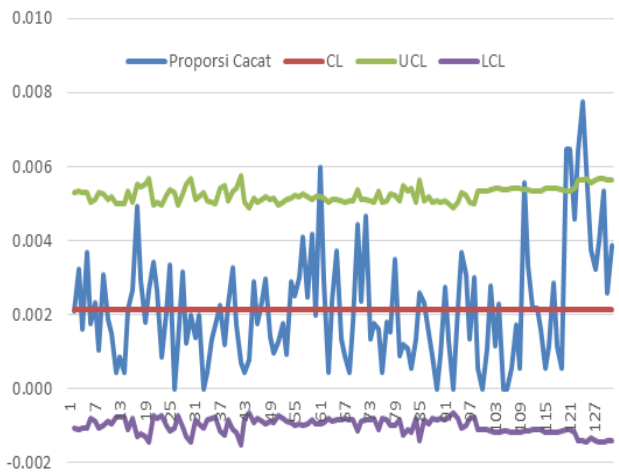

Figure 3. P-chart diagramcocoa oil defective products consequences of incompatibility of taste.

***c. Color*:** The calculation results P-Chart for defective products caused by color mismatches in the cocoa oil industry in the cocoa oil center area in Southeast Sulawesi, it shows that from the calculation results obtained a Ṕ value of 0.00104 and a 1-Ṕ value of 0.99896, and a CL value of 0.0010 . The results of the P-Chart calculation show that there are several industrial samples that produce cocoa oil with the proportion of defective products due to color mismatches that are above the highest threshold. This production sample is in industrial samples 56-61, and 120 - 124. If seen from the distribution of industrial samples, the cocoa oil industry in the North Kolaka Regency and Kolaka Regency areas is the industrial sample that experiences the most product defects caused by non-conformance. color above the maximum threshold. The P-Chart diagram for calculating defective cocoa oil products due to color mismatch in the cocoa oil industrial center area in Southeast Sulawesi can be seen in Fig. 4.

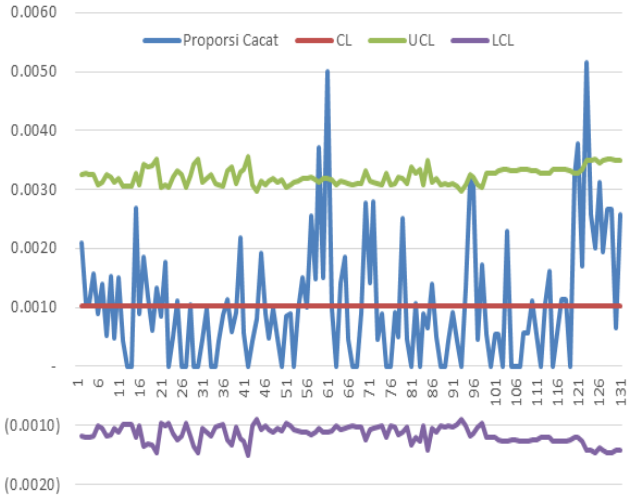

Figure 4. P-chart diagramcocoa oil defective products consequences of color mismatch.

***d. Water content*:** The calculation results P-Chart for defective products caused by mismatches in moisture content in the cocoa oil industry in the cocoa oil center area in Southeast Sulawesi, it shows that from the calculation results obtained a Ṕ value of 0.01979 and a 1-Ṕ value of 0.98021, and a CL value of 0, 0198. The results of the P-Chart calculation show that there are several samples of industries that produce cocoa oil with a proportion of defective products due to a mismatch in water content that is above the highest threshold. This production sample is in industrial samples 56-61, 106, and 116. If seen from the distribution of industrial samples, the cocoa oil industry in the North Kolaka Regency, East Kolaka Regency and Kolaka Regency areas is the industrial sample that experiences the most product defects. caused by a mismatch in water content above the maximum threshold. The P-Chart diagram for calculating defective cocoa oil products due to a mismatch in water content in the cocoa oil industrial center area in Southeast Sulawesi can be seen in Figure 5.

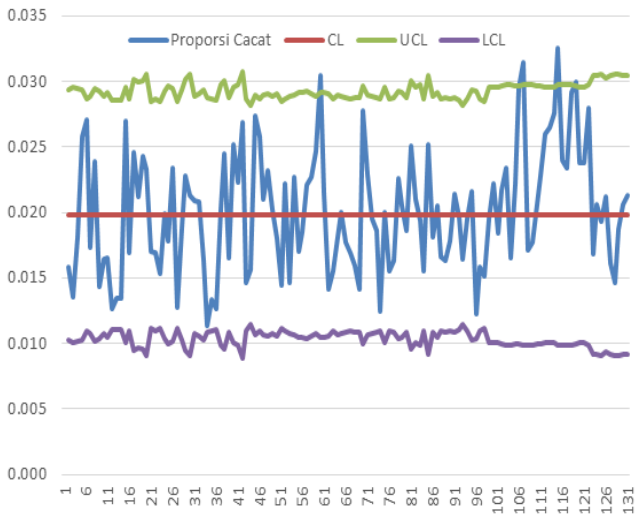

Figure 5. P-chart diagramcocoa oil defective products due to mismatch in water content.

***Analysis*:** Stages analysis in quality control using the six sigma method aims to identify important problems that cause defects in cocoa oil products. At this stage, the analysis used is the Pareto diagram and Fishbein diagram. The results of the Pareto Diagram calculation, cocoa oil industry products in the cocoa oil center area in Southeast Sulawesi, can be seen in Table 1.

Table 1. Defective cocoa oil products based on type.

No.	Types of product defects	No. of defects (ml)
1	Smell Incompatibility	1,268
2	Taste Incompatibility	543
3	Color Mismatch	265
4	Water Content Mismatch	5,065

Source: Data Collection Results, 2024

Furthermore, based on the data in Table 1, the calculation results for the Pareto Table for defective cocoa oil products based on type can be seen in Table 2.

Table 2. Pareto data calculation results defective cocoa oil products based on type.

No.	Type of defect	No. of defects (ml)	Cumula-tive No. of defects (ml)	Percen-tage (%)	Cumu-lative Percent age (%)
1	Smell Incompatibility	1,268	1,268	17.74	17.74
2	Taste Incompatibility	543	1,811	7.60	25.34
3	Color Mismatch	265	2,076	3.71	29.05
4	Water Content Mismatch	5,070	7,146	70.95	100.0
	Total	7,146		100	

Source: Analysis Results, 2024

Based on the results of calculating Pareto data on defective cocoa oil products according to the type of defect, the results are then obtainedil Pareto diagram in Figure 6.

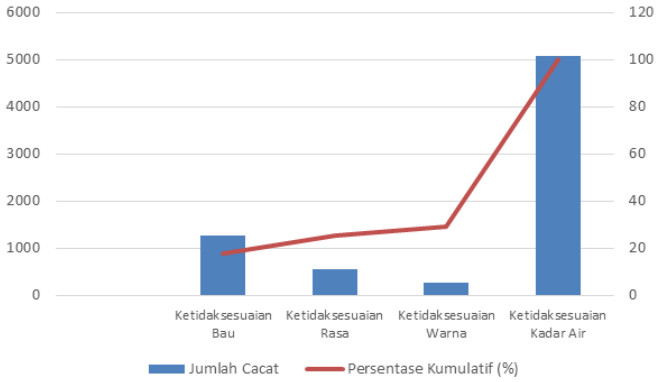

Figure 6. Diagram pareto defective products according to the type of defect.

After carrying out analysis using diagrams pareto, then analysis is then carried out using a fishbein diagram. This diagram is used to graphically present the causes of a problem to determine the cause and effect of a problem or what factors cause defects in cocoa oil products. The results of preparing a fishbein diagram of factors causing defective products in cocoa oil industry products in the cocoa oil industry center area of Southeast Sulawesi can be seen in Figure 7.

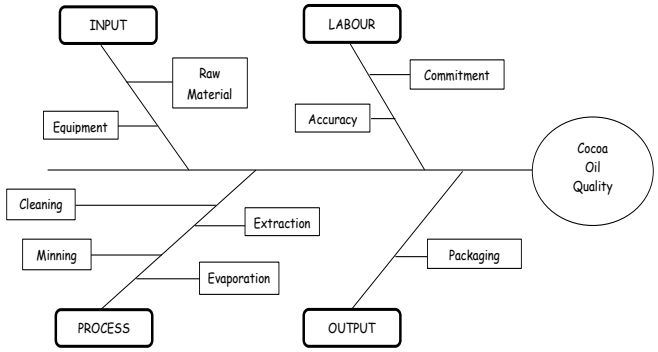

Figure 7. Cause and effect diagram (fishbein) determining factors of cocoa oil product defects.

***Improve*:** Improve is a stage in quality control using the six sigma method which aims to identify improvement efforts that can be made to repair defective products in order to improve the quality of cocoa oil products. At this stage, the improvement efforts offered in controlling the quality of cocoa oil are obtained based on the results of the focus group discussion (FGD) (Soemohadiwidjoyo, 2017; Costa *et al.*, 2021; Gupta *et al.*, 2020). The FGD results for the improvement stage can be seen in Table 3.

Table 3. Proposed improvements cocoa oil quality.

Factor	Problem	Solution
Raw Material (Cocoa Beam)	The water content of dry cocoa beans is relatively high	A larger cocoa bean drying medium is required
	Moldy dried cocoa beans	Fermentation measures need to be carried out to improve the quality of cocoa beans
	Dried cocoa beans are dirty and mixed with other substances that can affect the quality of the cocoa beans	Carry out selection and selection of raw material poles that prepare raw materials of good quality
	Moist cocoa beans	
	Cocoa bean pulp content is still relatively high	
Equipment	The equipment used in the process of preparing cocoa beans is very simple	It is necessary to procure new equipment both for the preparation of raw materials and for the production process
	Production equipment is considered old and still traditional	
	There is some equipment that is damaged and can no longer be used	
Extraction Process	The use of hexane solution for the extraction process is not able to release the aroma/smell of cocoa oil	It is necessary to use an ethanol solution to replace hexane in the extraction process
		There needs to be a partnership with the ethanol solution supplier in South Sulawesi Province, considering that the price of ethanol in industrial locations is very high.
Evaporation Process	Evaporation vacuum equipment is no longer economical	It is necessary to replace the evaporation vacuum with a new one so that the evaporation process can be more optimal
Labor Accuracy	The production knowledge possessed by workers is inadequate	There is a need for training and assistance for industrial workers, especially in adopting new production technologies
		It is necessary to improve digital literacy skills for workers so they can update the latest production technology independently
Labor Commitment	Low quality commitment of workers	A persuasive approach is needed to increase work commitment
	The workers' sense of belonging to the industry is relatively low	Additional forms of financial motivation for workers are needed
	Low work motivation	
Packaging	Low quality of packaging media	There is a need for better housing/packaging equipment
	Packaging raw materials are relatively expensive because they are supplied from other regions	There is a need for partnerships with packaging raw material suppliers in order to obtain packaging raw materials at lower prices
Milling Process	The milling equipment is quite old and no longer economical	It is necessary to replace new milling equipment so that the milling process can be more economical
Cleaning Process	The equipment used in the cleaning process for production is very simple	It is necessary to add some cleaning equipment
	The clean water used in the cleaning process is classified as poor	It is necessary to have a clean water source that is used for the cleaning process

Source: FGD Results, 2024

***Controls*:** Control is a stage that aims to supervise and control efforts to overcome defects in cocoa oil products that have been produced at the improve stage. At this stage, the analysis used is quality control group analysis. Quality control cluster analysis is carried out by monitoring each stage, starting from raw material preparation, production process stages, and packaging stages (Soemohadiwidjoyo, 2017; Costa *et al*., 2021; Gupta *et al*., 2020).

***a. Quality control group for raw material preparation stages*:** Control stage in material preparation standards are carried out by; selecting the location of the source of supply of dry cocoa beans. This is done so that the industry knows which sources of raw materials can be used as raw material supply partners. Apart from that, it is also necessary to control the storage location for raw material stock, especially in terms of maintaining cleanliness and air temperature at the storage location.

***b. Production stage quality control group*:** The control stage for the production process is carried out by method; control the physical condition of equipment that will be used in the production process. Apart from that, the control process at the production stage is also carried out by assessing the readiness of the soft skills and hard skills of the workers carrying out the production process. Then, the control stage is also carried out by monitoring the availability of production supporting materials, such as; ethanol, fuel, and other supporting materials.

***c. Packaging stage quality control group*:** The control stage for the packaging process is carried out by monitoring and supervising the equipment used in the packaging process. Apart from that, the control process in this packaging stage is carried out by monitoring the availability of packaging supporting materials, such as; quality of packaging bottles. Then, the packing stage control process is also carried out by evaluating the final packaging results, such as; assess whether there are no packaging defects that could cause damage to the cocoa oil.

***Conclusion*:** The results of research on quality control of cocoa oil industry products using the six sigma method provide several conclusions, namely;

1. The results of the check sheet and p-chart analysis show that the cocoa oil production process in the cocoa oil centre area in Southeast Sulawesi Province is classified as inefficient. This is proven by the fact that 17.74% of cocoa oil products have product defects.
2. The types of product defects found in cocoa oil products in the cocoa oil center area of Southeast Sulawesi Province are; smell mismatch, taste mismatch, color mismatch, and moisture content mismatch.
3. The results of the Pareto Diagram analysis show that there are 17.74% of defective products caused by smell mismatches, 7.60% of defective products caused by taste mismatches, 3.71% of defective products caused by color mismatches, and 70% of defective products caused by color mismatches. 95% of defective products are caused by a mismatch in water content.
4. The results of the Fishbein Diagram analysis show that there are 9 (nine) factors which are the main problems in improving the quality of cocoa oil products, namely; raw material, equipment, cleaning, milling process, extraction process, evaporation process, labor commitment, labor accuracy, and packaging.
5. The results of the improve six sigma analysis show that several solutions are needed to improve the quality of cocoa oil products, namely; (1) it is necessary to replace several production equipment, such as; fermentation tools, drying machines, production equipment, use of ethanol solution for the extraction process, training and assistance for workers, preparation of packaging equipment, and providing financial motivation for workers.
6. The results of the quality control group analysis as a control analysis show that to improve the quality of cocoa oil in the cocoa oil center area in Southeast Sulawesi Province, supervision and control must be carried out at the stages of raw material preparation, production process and packaging process.

***Authors' contributions*:** Conceptualization (Sudirman Zaid; Nasrul); Methodology (Sudirman Zaid; Nasrul; Wahyuniati); Validation (Wahyuniati); Formal Analysis (Sudirman Zaid; Nasrul; Wahyuniati); Investigation (Wahyuniati); Resources (Sudirman Zaid); Data Curation (Sudirman Zaid; Nasrul; Wahyuniati); Writing – Original Draft Preparation (Sudirman Zaid; Nasrul); Writing – Review & Editing (Sudirman Zaid); Visualization (Sudirman Zaid; Wahyuniati); Supervision (Sudirman Zaid); Project Administration (Wahyuniati).

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***Ethical statement*:** All procedures carried out in studies not involving animals

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***Availability of data and material*:** We declare that the submitted manuscript is our work, which has not been published before and is not currently being considered for publication elsewhere.

***Code availability*:** Not applicable

***Consent to participate*:** All authors participated in this research study.

SDG's addressed: Zero Hunger, Gender Equality.

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