ISSN 2087-3336 (Print) | 2721-4729 (Online)

TEKNOSAINS: Jurnal Sains, Teknologi dan Informatika
Vol. 11, No. 1, January 2024, page. 176-186
http://jurnal.sttmcileungsi.ac.id/index.php/tekno
DOI: 10.37373

Quality control to reduce production defects using control chart, fishbone diagram, and FMEA

Yudha Adi Kusuma[1*], Halwa Annisa Khoiri[1], I Made Aryantha A.[2], Bagus Herlambang[1]

[1*] Industrial Engineering, Universitas PGRI Madiun, Indonesia, 63117, AURI Street No. 14-16, Madiun City, East Java
[2] Industrial Engineering, Universitas Komputer Indonesia, Indonesia, 40132, Dipati Ukur Street No. 102-116, Bandung City, West Java

*✉ yudhakusuma@unipma.ac.id

Submitted : 24/12/2023 Reviseded : 04/01/2024 Accepted: 12/01/2024

ABSTRACT

Quality improvement is necessary to overcome the occurrence of defective products during the production cycle. The occurrence of defective products is difficult to avoid. Therefore, the Sugar Factory (SG) business unit at PT XYZ began to implement quality control for sugar production. Based on these events, an analysis of quality measurement is carried out through this research. The methods used in this research are control chart, fishbone diagrams, and failure mode and effect analysis (FMEA). The results of the control map measurement using the p-chart and u-chart show that there is no sugar production process that is out of control. Although nothing is out of control, it is also necessary to analyze it using a fishbone diagram to determine the cause of the defects that occur. The results of the measurements with FMEA can be known sub-factors that have the highest RPN, namely negligence of operations, poor sugar cane sorting, changes in production schedules, incomplete repair areas, and poorly organized layouts. From the results of data processing, it can be seen that quality control needs to be carried out by the company. One of them is by making standard operating procedures (SOP) related to the sugar processing process. In addition, the raw materials for making sugar also need to be considered, so that the process will produce sugar with better quality.

Keyword: Control chart, fishbone diagram; FMEA; sugar factory

1. INTRODUCTION

Increasingly fierce competition encourages companies to always improve. The process of improvement involves effective and efficient ways to achieve the goals that have been set [1]. There are many ways to realize the success of company goals. One of them is through quality improvement [2]. The existence of quality is the main requirement in order to be accepted by consumers, so companies are required to maintain their quality [3]. The existence of quality is certainly achieved through a process that is in accordance with market standards [4],[5]. Conformity with existing standards is a key factor that continues to be maintained. Actions to maintain quality aim to avoid changes in production results within certain limits [6]. If the quality is not consistent, it can make customers turn away from competitors. The problem of turning away customers can be anticipated through quality control and satisfaction [7].

There are three types of quality control, including raw materials, processes, and end products. The three types of quality control are interrelated and connected to each other. Quality control should not be done carelessly. Comprehensive planning, both upstream and downstream, is the company's benchmark for carrying out quality control [8]. The company's desire to always improve quality control needs to always be prioritized. Revamping consistently lowers the percentage of defects so that mistakes do not reoccur [9],[10]. Some forms of disability that need to be eliminated include accidents, damage, and complaints [11]. Therefore, quality control requires planning by adjusting the applicable SOPs [12].

The quality control stage is also applied by PT XYZ to one of the Sugar Factory (SF) business units in Madiun City. SF's business unit activity at PT XYZ is to process sugarcane into White Crystal Sugar (WCS). **Figure 1** shows the stages of the production process in the SF business unit at PT XYZ. In general, the sugar production process goes through five processes. The stages of quality control by SF business units at PT XYZ aim to control production in accordance with time, budget, and targets. If the quality of production is low, it will also indirectly have an impact on productivity [13]. Therefore, SF's business unit at PT XYZ carries out quality control, starting from raw materials to products. Sugarcane raw materials before entering the milling process are sought to be free from sticking impurities. The abundance of impurities affects the yield of sugar obtained. In addition, activities that interfere with the running of the production process as much as possible are anticipated immediately.

Figure 1. Production process in sf business unit at pt xyz

Although the quality control process has been implemented, under certain conditions, there are still problems that cannot be avoided. Some incidents that reduce the quality of sugar in the SF business unit at PT XYZ include wet scrap sugar, ash, clumped sugar, and molasses sugar [14]. The incident occurred during the production process. Process repetition must be performed, but when it happens, it is inefficient [15]. In addition to being inefficient, process repetition increases energy use beyond the planned capacity before the production process takes place [16]. The final stage of the production process is also not spared from quality constraints. Types of obstacles that occur include torn packaging, dirty packaging, detached seams, and underexposed prints [17]. The emergence of these obstacles, if not resolved immediately, can burden production costs such as machine maintenance, raw material costs, and labour costs [18]. he high cost of production causes the profit received by SF's business unit at PT XYZ to be reduced.

In an effort to overcome the above problems, it is necessary to control the quality of sugar products in the SF business unit at PT XYZ. Quality control methods using Control Charts, Fishbone Diagrams, and Failure Mode and Effect Analysis (FMEA). The purpose of quality control in this study is to reduce the failure rate in the sugar production process so as to produce quality products. In addition, this study also identified the factors that caused the occurrence of defective products and determined improvement proposals in the form of preventive measures to reduce defective products.

2. METHOD

This research examines the object of the production process, especially GKP in the SF business unit at PT XYZ. The research period is two months and starts on October 1, 2023, until November 30, 2023. This stage of research begins with field observations and literature studies. Observation activities and literature studies aim to strengthen researchers' knowledge of quality control aspects so as to reduce errors in taking action during the study [19]. Stages of observation and literature study are considered in determining problem identification. Determination of problem identification based on findings of errors in quality that arise during the production process [20]. Problem findings that are worthy of research require support for data review.

The existence of data in research is obtained through the process of data collection. In this study, the data is divided into primary data and secondary data. Primary data is obtained through observations and surveys within the scope of the SF business units at PT XYZ. Primary data, such as production performance data, employee performance data, etc. Primary data is obtained from historical data within the scope of SF business units in PT XYZ and other parties who have the authority to release data credibly. Secondary data, such as raw material data, sugar production data, etc. The results of data collection are required in the data processing stage. All collected data is processed using appropriate research methods. This research uses three methods, namely:

1) Control chart

   The use of control charts to find out whether deviations occur is still within the tolerance limits for deviations [21]. The control chart shows changes between times and is plotted in order [22].

The content of the control chart contains three lines, namely the control line, which shows the middle or average value, the lower control line, which is below the centre line, and the upper control line, which is above the middle value [23]. The use of control charts in this study includes a p chart and a u chart. The selection of the p chart and the u chart due to the sample size varies [24] depending on the capacity of the sugarcane raw materials that enter the processing process. The calculation formula for the p chart and the u chart is in **Table 1**.

Table 1. Calculation formula of p-chart dan u-chart

p-Chart Calculation			
Formula	**Description**		
BKA_P / $UCL_P = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$	BKA_P / UCL_P	=	Upper Control Limit on p chart
	BKB_P / LCL_P	=	Upper Control Limit on p chart
BKB_P / $LCL_P = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$	GK_P / CL_P	=	Central Line on p chart
	p_i	=	Proportion of defects in each observation
GK_P / $CL_P = \bar{p} = \frac{\sum_{i=1}^{m} x_i}{n.m} = \frac{\sum_{i=1}^{m} p_i}{m}$	n	=	The number of samples per observation
	m	=	The number of observations
u-Chart Calculation			
Formula	**Description**		
BKA_U/ $UCL_u = \bar{u} + 3\sqrt{\frac{\bar{u}}{n}}$	BKA_U / UCL_U	=	Upper Control Limit on u chart
	BKB_U / LCL_U	=	Upper Control Limit on u chart
BKB_U / $LCL_u = \bar{u} - 3\sqrt{\frac{\bar{u}}{n}}$	GK_U / CL_U	=	Central Line on u chart
	c_i	=	The number of errors per observation
GK_U / $CL_u = \bar{u} = \frac{\sum_{i=1}^{m} c_i}{nm}$	m	=	The number of observations
	n	=	Sample size

2) Fishbone diagram
Fishbone diagrams contribute to solving problems. Problem-solving steps related to causation are in the form of diagrams [25]. Findings of problem causation are identified from potential causes of effects and problems and analysed through brainstorming activities [26]. These causes generally lead to five problems, namely humans, machines, materials, methods, and the environment [27]. An example of the results of making a fishbone diagram can be seen in **Figure 2** [28].

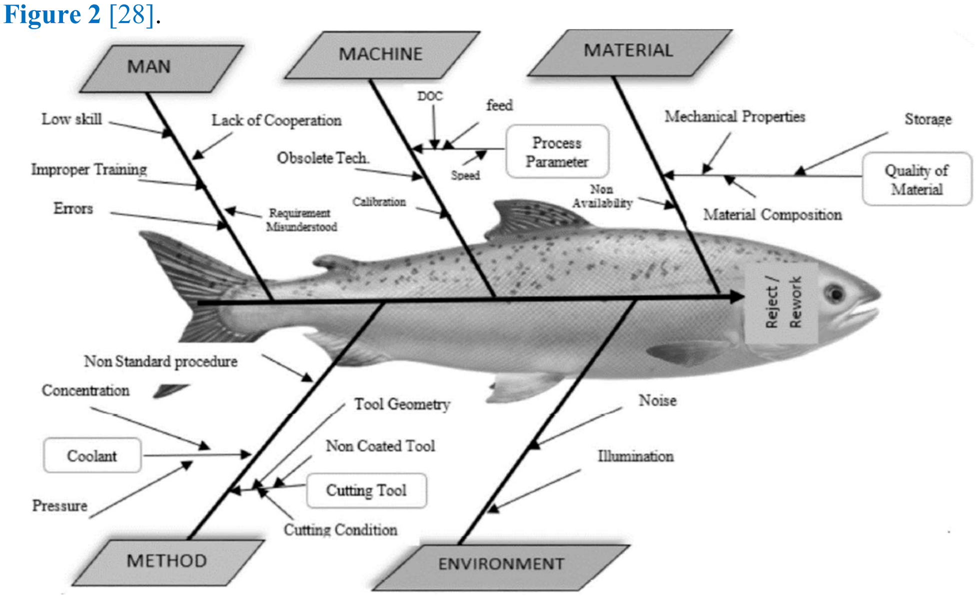


Figure 2. Fishbone diagram example

3) *Failure Mode and Effect Analysis* (FMEA)
FMAE is part of a procedure that is useful in identifying and preventing possible failures. The FMEA method anticipates failure through an assessment of the source and root cause of the

problem [29]. The results of the FMEA method assessment are in the form of a risk priority number (RPN) to determine the priority of failure modes based on the multiplication of values from the levels of severity, occurrence, and detection [30]. The severity value shows the severity of the consequences caused, the occurrence value indicates the probable level of the cause of the failure during the process, and the detection value shows the level of control over the failure that occurred [5]. Parameters in the assessment of severity, occurrence, and detection levels can be determined based on **Table 2** [31].

Table 2. Assessment parameters on severity, occurrence, and detection

Severity		
Effect	Severity of effect	Rating
Very Low	No impact	1
Low	System functional with little disruption	2
	System still functional despite minor performance reduction	3
Moderate	System still functional but with a noticeable performance drop	4
	System unusable without harm	5
High	System unusable with little damage	6
	System unusable due to equipment failure	7
	System unusable due to destructive failure that doesn't jeopardise safety	8
Very High	Extremely high rating of severity when a possible mode of failure impacts the safe operation of the system's components with alerts	9
	Extremely serious when a possible failure mode abruptly affects the secure functioning of the system	10

Occurrence		
Probability	Probability of occurrence	Rating
Very Low	Failure is not likely.	1
Low	1 in 150000	2
	1 in 15000	3
Moderate	1 in 2000	4
	1 in 400	5
	1 in 80	6
High	1 in 20	7
	1 in 8	8
	1 in 3	9
Very High	> 1 in 2	10

Detection		
Detection	Likelihood of detection	Rating
Very High	Design control will identify the failure mode that follows the possible cause or mechanism.	1
High	Very high probability that the design control will identify the failure mode that follows the possible cause or mechanism	2
	Possibility that the design control will identify the failure mode and its possible cause or method	3
Moderate	Moderately high probability that the design control will identify the mechanism or possible cause of the failure and its following manner	4
	Moderate likelihood the failure mode that follows a possible cause or mechanism will be identified by the design control.	5
	There is little likelihood that the design control will identify the probable cause, method, and failure mode.	6
Low	Extremely unlikely that the design control would identify a possible cause or mechanism and the failure mode that follows.	7
	In the unlikely event of a failure, the design control will identify the probable cause and process.	8
	Extremely unlikely that the design control would identify the mechanism or possible cause and the failure mode that follows.	9
Very Low	Potential causes, mechanisms, and ensuing failure modes can't be identified	10

by design control.

The results of data processing are useful in determining conclusions and suggestions for research. The determination of conclusions aims to explain the research hypothesis and know the overall results of the study [32]. he explanation of the research results is brief and to the point. Providing advice on research is useful in providing recommendations for improvements to similar research in future studies [33]. Recommendations for improvement can be in the form of adding methods or parameters from previous studies.

3. RESULTS AND DISCUSSION

The quality measurement in this study is at the cane processing stage and the sugar packaging stage. The quality measurement process starts from May 15, 2023 to August 9, 2023. The quality measurement data for sugar production is shown in **Table 3**. The quality measurement is done through 85 observations, where the data is collected and entered into the tables only during the production process, so if there is a production stop hour, it is not included in the classification of the observation data. The observation process is limited to 8 hours because the measurements are made during the morning shift between 08:00 and 16:00. During the observation, there were two stop hours, namely on June 18, 2023 and June 30, 2023. Types of sugar defects during the sugar production process include krikilan, molasses, wet sugar, inappropriate color, dirt and ashing. Types of sugar packaging defects include underexposed mold, torn packaging, dirty packaging, and detached seams.

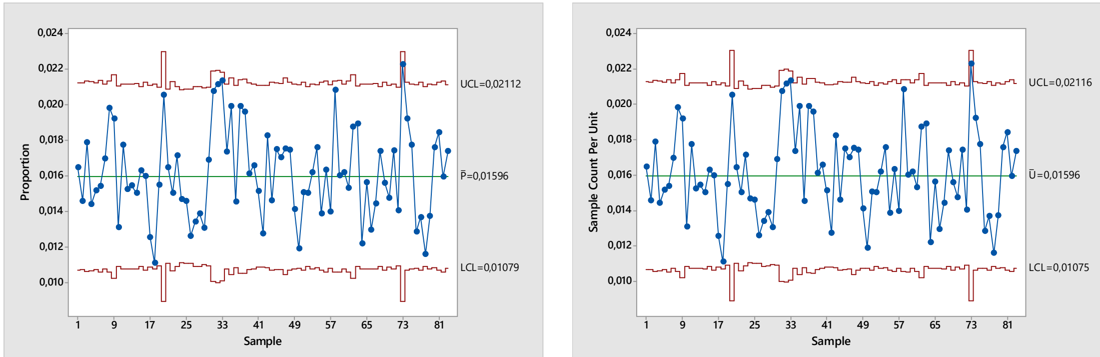
Table 3. Production and packaging process defect data

Data	Date	Production (ton)	Types of Production Process Defects						Defects Number
			Clumped Sugar	Molasses	Wet Sugar	Color Discrepancy	Dirty	Refined	
1	15 / 05 / 2023	5100	17	19	14	8	15	11	84
2	16 / 05 / 2023	5150	8	12	12	18	11	14	75
…	…	…	…	…	…	…	…	…	…
82	08 / 08 / 2023	4900	9	11	19	16	11	12	78
83	09 / 08 / 2023	5300	13	17	20	20	10	12	92

Data	Date	Packaging Quantity (units)	Types of Packaging Defects				Defects Number
			Underexposed Prints	Torn Packaging	Dirty Packaging	Detachable Seam	
1	15 / 05 / 2023	10200	18	15	17	11	61
2	16 / 05 / 2023	10300	14	20	16	19	69
…	…	…	…	…	…	…	…
82	08 / 08 / 2023	9800	13	12	14	20	59
83	09 / 08 / 2023	10600	17	17	17	16	67

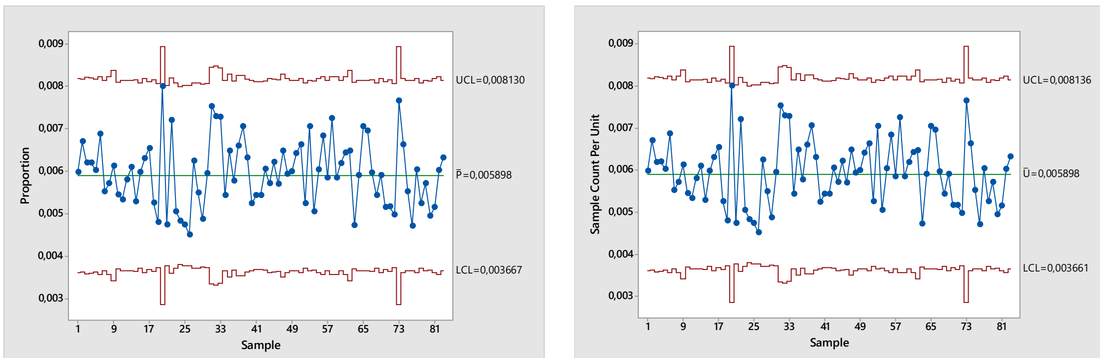
The results of the production and packaging defect data become inputs for the processing of control charts. In this study, we used control charts (p chart and u chart) because the data varied. **Figure 3** and **Figure 4** show the results of p chart and u chart against defects in sugar production and packaging. The results of the p chart and u chart were formed from 83 observations, and the data were taken during the morning shift. In general, the occurrence of defects is still within the control limits. Nothing comes out of UCL or LCL. There is no need to repeat calculations due to out-of-control data. However, further action must be taken to minimize the occurrence of defects. Note that defects during production time can reduce the profit of SF's business unit at PT XYZ. The desire of PG's business unit at PT XYZ is to find the source of the risk of production defects and achieve zero waste so that the sugar production process will not be disrupted in the coming year.

ISSN 2087-3336 (Print) | 2721-4729 (Online)
DOI 10.37373/tekno.v11i1.968



(a) (b)

Figure 3. p chart (a) and u chart (b) on defects in the sugar production process



(a) (b)

Figure 4. p chart (a) and u chart (b) on defects in the sugar packaging process

Although the conditions of the emergence of defective products from the production and packaging processes are still in a reasonable stage or not out of control, it is also necessary to trace the cause of each type of defect. The method used to determine the root cause of the defect in this study uses a fishbone diagram. The fishbone diagram classifies root causes into five categories: people, methods, materials, machines, and environment. Each category is described in detail, from the causes of the problem to the presence of a more detailed filling of fish bones. The fishbone diagram result in this study can be seen in **Figure 5**. A more detailed explanation is as follows:

1) Man

   Employees are engaged in sugar production activities. In the sugar production process, it is possible to produce defects due to employee errors. Some mistakes caused by employees such as negligence, inaccuracy, discipline and lack of training. The causes of employee negligence are fatigue, lack of calculation, excess water administration and centrifugation errors. It is not uncommon for employees to be less careful to cause steam pipes to overturn, steam cleaning is less clean and vacuums are closed. In addition, sometimes lack of discipline also affects employee performance. How many examples of actions of employees who lack discipline such as leaving the office during the production process and not listening to instructions from the foreman. The high occurrence of a decrease in production quality by employees can also be caused by lack of training activities. Mistakes that often arise due to employees rarely participating in training are lack of accuracy, not understanding the quality of materials and machine setting errors.

2) Method

   Method refers to work instructions that must be followed during the production process. The cause of failure during production caused by method factors is changes in production schedules, and Standard Operating Procedures (SOPs) have not been maximized. Often, schedule changes

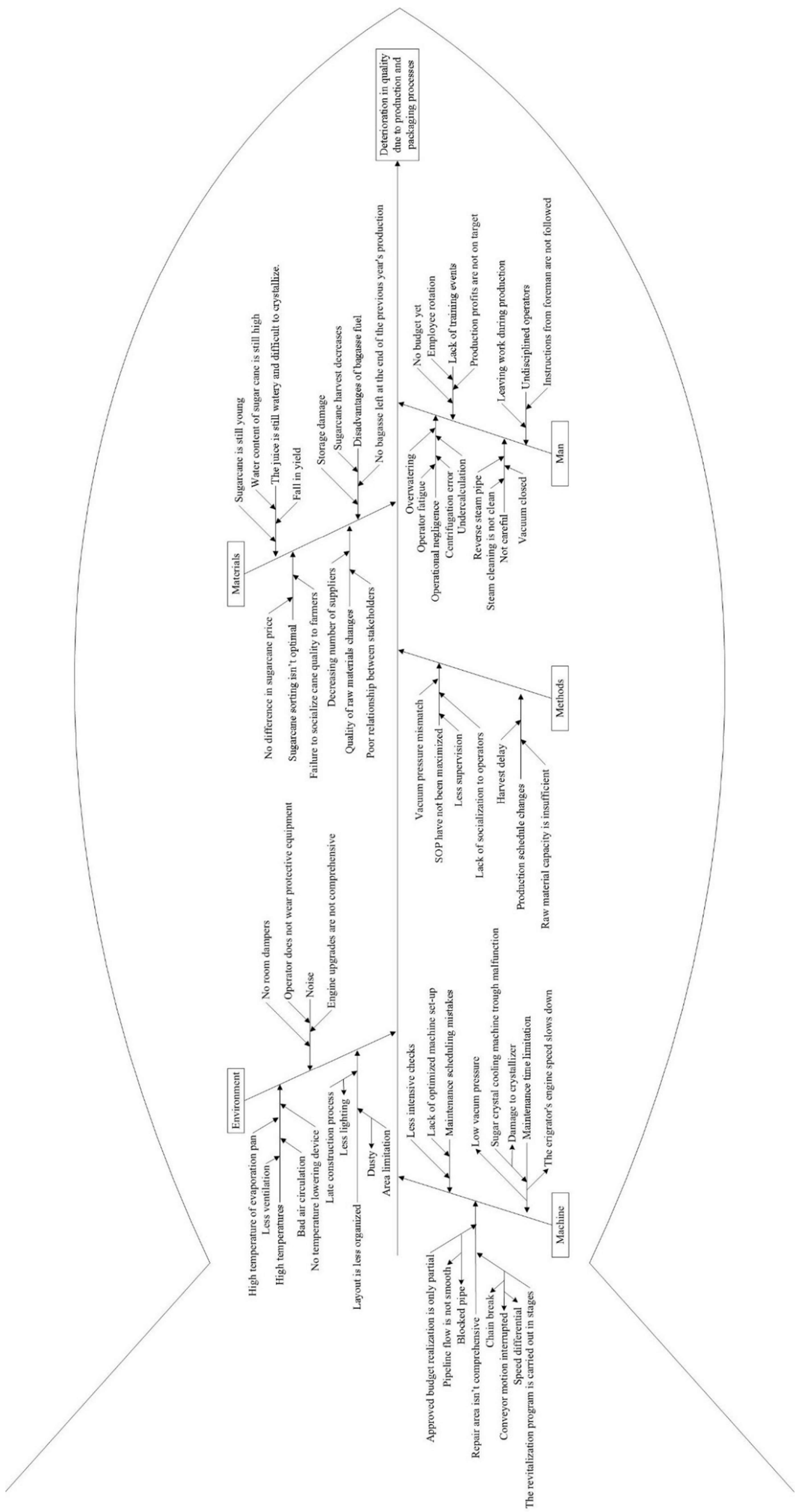


Figure 5. Fishbone diagram related to defective results due to production and packaging processes

are made following conditions that occur in the field. The schedule change is related to the condition of sugarcane raw materials. If the capacity of raw materials is not sufficient and natural factors that affect the decline in sugarcane harvests can make changes to the production schedule, In some cases, at work stations, SOPs are often not obeyed by employees. The cause of the occurrence is a lack of supervision and socialization. One of the impacts caused is a mismatch in vacuum pressure.

3) Machine
The existence of machines serves as the means for producing sugar. Not infrequently, the condition of the engine is not prime, resulting in problems with the occurrence of production defects. Factors that affect machine performance during production are limited maintenance time, maintenance scheduling errors, and incomplete repair areas. Limited maintenance time results in low vacuum pressure, malfunction of the sugar crystal cooling trough, and slowed erygrator engine rotation. The repair area is not comprehensive, and the impact that occurs is that the flow of the cooking pan pipe is not smooth and the conveyor motion is disrupted. Maintenance scheduling errors are caused by less intensive checks and suboptimal engine set-up.

4) Material
Material refers to the need for raw materials during the sugar production process. The existence of raw materials is divided into main and companion raw materials. If the quality of raw materials does not match specifications, it can result in decreased production results. The causative factors for raw materials not complying with specifications are poor sorting of sugarcane and changes in sugarcane quality. The impact caused if the sugarcane received is not in accordance with the quality is that the sap is difficult to crystallize. In addition, sugarcane fields whose area is decreasing are resulting in fuel shortages.

5) Environment
Environmental conditions are related to the area of the plant. Often, poor area management results in production results that do not meet the planned target. In the case of the sugar factory area, the cause of constraints in the environment is a poorly organised layout. The impact is that the room is hot, and noise occurs. Room heat occurs due to lack of ventilation, no temperature-lowering device, air circulation that is not smooth, and high-temperature evaporation. Noise in the production room is caused by engine upgrades that have not been completed; operators do not use personal protective equipment; and the room has no dampers.

In addition to knowing the cause of the occurrence of production defects, this study also assessed the source and root cause of the problem. The method used in the assessment is FMEA. Evaluation of FMEA on each sub-factor of man, machine, material, method, and environment. Table 4 shows the results of the FMEA assessment. The RPN value is obtained from severity (S) × occurrence (O) × detection (D). The average RPN value calculated is 40.81. It is known from the results of the FMEA calculations that each factor has the highest RPN value. The sub-factors of each factor that have the highest RPN are negligence of operation, poor sorting of sugarcane, changes in production schedules, areas of improvement that are not thorough, and the layout that is not organised.

Table 4. RPN calculation

Factor	Sub Factors		S	O	D	RPN
Man (A)	A1	Not careful	7	7	9	441
	A2	Undisciplined operators	8	5	8	320
	A3	Lack of training events	8	7	8	448
	A4	Operation negligence	9	8	10	720
Material (B)	B1	The juice is still watery and difficult to crystallize.	6	8	9	432
	B2	Sugarcane sorting isn't optimal	9	7	8	504
	B3	Quality of raw materials changes	8	6	8	384
	B4	Bagasse shortage	6	6	10	360
Method (C)	C1	Production schedule changes	9	8	9	648
	C2	Standard Operating Procedures (SOP) have not been maximized	7	5	8	280
Machine	D1	Maintenance scheduling mistakes	6	8	7	336

Factor		Sub Factors	S	O	D	RPN
(D)	D2	Maintenance time limitation	10	5	7	350
	D3	Repair area isn't comprehensive	7	8	8	448
Environment (E)	E1	High temperatures	5	6	7	210
	E2	Noise	6	5	6	180
	E3	Layout is less organized	10	6	8	480

Selection of the highest RPN value from one of the subfactors on the recommendation of the PG business unit at PT XYZ for further corrective, preventive and countermeasures to be taken. The types of actions that can be taken are listed in **Table 5**. The contents of **Table 5** are causes, probability levels, and contingency plans. The results of **Table 5** showed that there were 11 subfactor triggers, 10 possible treatments, and 11 contingency plans that could be done.

Table 5. Response to high RPN subfactors

Sub Factors	Cause	Likelihood	Contingency Plan
Lack of training events	1) No budget yet 2) Employee rotation 3) Production profits are not on target	Mitigation, Avoidance	1) Apply for technical advising activities each semester. 2) Evaluate performance and penalize employees who are low contributors to the production process.
Sugarcane sorting isn't optimal	1) No difference in sugarcane price 2) Failure to socialize cane quality to farmers	Retention, Transfer	1) Provide the price difference between clean cane and dirty cane. 2) Collaboration between multiple parties involved in the fulfillment of sugarcane raw materials.
Production schedule changes	1) Harvest delay 2) Raw material capacity is insufficient	Transfer, Sharing	1) Planting time change. 2) Sugar cane mechanization. 3) Provide cheap credit to sugar cane farmers.
Repair area isn't comprehensive	1) Approved budget realization is only partial 2) The revitalization program is carried out in stages	Mitigation, Transfer	1) Modifications by use of other factory equipment that is no longer in production. 2) Maximize the performance of equipment that can be used through its lifecycle.
Layout is less organized	1) Area limitation 2) Late construction process	Avoidance, Sharing	1) Clean area before and after production. 2) Plan development in phases.

4. CONCLUSION

The conclusion of the research carried out on the quality control of sugar products is that the results of the measurements using p and u charts are known to be still at a reasonable level where there is no out of control. However, it is necessary to search for the cause of each type of defect. The results of identifying the causes of defects using the fishbone diagram method are classified into five categories: people, methods, materials, machines, and environment. Assessing the subfactors of people, machines, materials, methods, and environment using the FMEA method. the highest RPN value for which countermeasures are needed. The selection of countermeasures is based only on the highest RPN value in the subfactor, as recommended by the PG business unit at PT XYZ. The findings included in the high category subfactors are negligence of operations, poor sorting of sugarcane, changes in production schedules, improvement areas that are not thorough, and the layout is not organized. The results of this study are not final. Improvements must be made for future research. It is also necessary to add other methods besides those in this study. The cost factor can be a reinforcement for the profit and loss analysis if you do not apply quality improvements in the production process.

REFERENCE

[1] J. Radianza and I. Mashabai, "Analisa Pengendalian Kualitas Produksi dengan Menggunakan Metode Seven Tools Quality di PT. Borsya Cipta Communica," *JITSA J. Ind. Teknol. Samawa*,

vol. 1, no. 1, pp. 17–21, 2020.
[2] Sulaeman, "Analisa Pengendalian Kualitas untuk Mengurangi Produk Cacat Speedometer Mobil dengan Menggunakan Metode QCC di PT INS," *J. Pasti*, vol. 8, no. 1, pp. 71–95, 2014.
[3] I. G. N. A. D. Putra, "Analisis Pengaruh Pengendalian Kualitas Produk dan Pengendalian Proses Produksi terhadap Peningkatan Produktivitas Produk," *Ekon. Keuangan, Investasi dan Syariah*, vol. 4, no. 4, pp. 1335–1341, 2023.
[4] Fadhlirrobbi, A. Sopiandi, L. Suliah, Savitri, and E. Sunarya, "Analisi Pengendalian Kualitas (Quality Control) dalam Meningkatkan Kualitas Produk (Studi Kasus Rumah Produksi Tempe Azaki)," *JIP J. Inov. Penelit.*, vol. 2, no. 10, pp. 3269–3272, 2022.
[5] M. B. Anthony, "Analisis Penyebab Kerusakan Hot Rooler Table dengan Menggunakan Metode Failure Mode And Effect Analysis (FMEA)," *J. INTECH Tek. Ind. Univ. Serang Raya*, vol. 4, no. 1, pp. 1–8, 2018.
[6] A. Nurholiq, O. Saryono, and I. Setiawan, "Analisis Pengendalian Kualitas (Quality Control) dalam Meningkatkan Kualitas Produk," *Ekonologi J. Ilmu Manaj.*, vol. 6, no. 2, pp. 393–399, 2019.
[7] S. M. Wirawati, "Analisis Pengendalian Kualitas Kemasan Botol Plastik Dengan Metode Statistical Proses Control (SPC) Di PT. Sinar Sosro KPB PAndeglang," *J. InTent*, vol. 2, no. 1, pp. 94–102, 2019.
[8] D. A. Nuryanto and W. Setiafindari, "Analisis Pengendalian Kualitas pada Pengolahan Produk Kulit dengan Metode Statistical Process Control pada UMKM Paris Leather," *Performa Media Ilm. Tek. Ind.*, vol. 20, no. 2, pp. 167–176, 2021.
[9] L. M. Ramdani and A. Z. Al Farity, "Analisis Pengendalian Kualitas pada Produksi Base Plate R-54 Menggunakan Metode Statistical Quality Control dan 5S," *J. Teknol. dan Manaj. Ind. Terap.*, vol. 1, no. 2, pp. 85–97, 2022.
[10] Y. A. Kusuma and M. R. Azzizi, "Pengelolaan Bahan Baku Ready Mix Menggunakan Pemilihan Alternatif Perencanaan untuk Meminimalkan Biaya Penyimpanan," *JENIUS J. Terap. Tek. Ind.*, vol. 3, no. 2, pp. 61–70, 2022.
[11] E. W. Asih, L. O. R. Rain, and A. Pohandry, "Analisis Pengendalian Kualitas Produk Teh Hitam dengan Pendekatan Lean-Six Sigma Method di PT. Teh XY," *J. Ind. Eng. Syst.*, vol. 2, no. 2, pp. 136–145, 2021.
[12] S. T. D. Sinaga, S. H. Putri, and T. Pujianto, "Analisis Pengendalian Kualitas Pada Proses Produksi Teh Hitam Menggunakan Metode Statistical Quality Control," *Teknotan*, vol. 17, no. 2, pp. 153–160, 2023.
[13] S. Noferanita, G. Jauhari, A. Neris, B. M. Si, and M. Eng, "Pengendalian Kualitas Gula Tebu dengan Metode Six Sigma di Koperasi Serba Usaha (KSU) Tabek, Talang Babungo Kabupaten Solok," *J. Sains Dan Teknol.*, vol. 20, no. 2, pp. 1–11, 2020.
[14] L. Sholiha and A. Syaichu6, "Analisa Pengendalian Kualitas Produk Gula Kristal Putih dengan Metode Seven Tools," *Sist. J. Ilmu - Ilmu Tek.*, vol. 13, no. 1, pp. 50–58, 2017.
[15] Suseno and R. A. Hermansyah, "Analisis Pengendalian Kualitas Produk Gula Menggunakan Metode Six Sigma Pada Pt Madu Baru," *SENTRI J. Ris. Ilm.*, vol. 2, no. 2, pp. 489–504, 2023.
[16] L. Permono, L. A. Salmia, and R. Septiari, "Penerapan Metode Seven Tools Dan New Seven Tools Untuk Pengendalian Kualitas Produk (Studi Kasus Pabrik Gula Kebon Agung Malang)," *J. Valtech*, vol. 5, no. 1, pp. 58–65, 2022.
[17] Y. Erdhianto, "Analisa Pengendalian Kualitas untuk Mengurangi Jumlah Cacat pada Kemasan Produk Gula Pasir PG Kremboong dengan Metode Seven Tools," in *Seminar Nasional Teknologi Industri Berkelanjutan I (SENASTITAN I)*, 2021, pp. 349–357.
[18] B. W. D. Nugroho, Ndoro Jatun Kuncoro Jakti, Muhammad Alif Nur Rochman, and Andung Jati Nugroho, "Analisis Pengendalian Kualitas Produk Gula dan Biaya Kualitas dalam Menunjang Efektivitas Produksi," *J. Teknol. dan Manaj. Ind. Terap.*, vol. 2, no. 2, pp. 72–81, 2023.
[19] Y. A. Kusuma and A. C. A. Bima, "Penerapan Kode Etik Keinsinyuran untuk Mengatasi Permasalahan Kegiatan Program Pengembangan Produk Unggulan Daerah (PPPUD)," *J. Ind. View*, vol. 4, no. 1, pp. 1–8, 2022.
[20] Y. A. Kusuma and S. M. Khoiroh, "Analysis of Village Infrastructure Project Success Factors

by Considering Implementation Risks," *Motiv. J. Mech. Electr. Ind. Eng.*, vol. 5, no. 2, pp. 351–364, 2023.

[21] D. Setyanita and N. Setyowati, "Pengendalian Mutu Gula di Pabrik Gula Rendeng Kabupaten Kudus," *Agrista J. Ilm. Mhs. Agribisnis UNS*, vol. 5, no. 1, pp. 13–24, 2017.

[22] R. H. Fouad and A. Mukattash, "Statistical Process Control Tools : A Practical guide for Jordanian Industrial Organization," *Jordan J. Mech. Ind. Eng.*, vol. 4, no. 6, pp. 693–700, 2010.

[23] B. Neyestani, "Seven Basic Tools of Quality Control: The Appropriate Techniques for Solving," 2017.

[24] Y. A. Kusuma and A. Z. Muttaqin, "Penerapan Quality Control dan Risk Management dalam Menjaga Mutu Produk," *J. Tek. Ind.*, vol. 11, no. 2, pp. 125–132, 2021.

[25] V. Jayakumar, F. Mohammed Ajmal Sheriff, A. Muniappan, G. Bharathiraja, and G. Ragul, "Implementation of Seven Tools of Quality in Educational Arena: A Case Study," *Int. J. Mech. Eng. Technol.*, vol. 8, no. 8, pp. 882–891, 2017.

[26] Deepak and D. Dhingra, "Application of Quality Control Tools in a Bicycle Industry: a Case Study," in *International Journal of Research in Engineering and Technology*, 2016, pp. 119–127.

[27] Stefry, M. S. Siagian, A. Zalukhu, and M. L. A. Sinabang, "Analisis Penyebab Rendahnya Tingkat Rendemen Produksi Gula pada Pabrik Gula XYZ Menggunakan Fishbone Diagram, Failure Mode Effect Analysis, dan Metode 5W+1H," in *TALENTA Conference Series: Energy and Engineering*, 2021, pp. 38–45.

[28] A. Tayal, N. S. Kalsi, M. K. Gupta, D. Y. Pimenov, M. Sarikaya, and C. I. Pruncu, "Effectiveness Improvement in Manufacturing Industry; Trilogy Study and Open Innovation Dynamics," *J. Open Innov. Technol. Mark. Complex.*, vol. 7, no. 1, pp. 1–21, 2021.

[29] J. Susetyo, M. Yusuf, and J. Geriot, "Pengendalian Kualitas Produk Gula dengan Metode Statistical Processing Control (SPC) dan Failure Mode and Efect Analysis (FMEA)," *J. Teknol.*, vol. 13, no. 2, pp. 127–135, 2020.

[30] P. S. K. Hanifah and I. Iftadi, "Penerapan Metode Six Sigma dan Failure Mode Effect Analysis untuk Perbaikan Pengendalian Kualitas Produksi Gula," *J. INTECH Tek. Ind. Univ. Serang Raya*, vol. 8, no. 2, pp. 90–98, 2022.

[31] Y. M. Wang, K. S. Chin, G. K. K. Poon, and J. B. Yang, "Risk Evaluation in Failure Mode and Effects Analysis using Fuzzy Weighted Geometric Mean," *Expert Syst. Appl.*, vol. 36, pp. 1195–1207, 2009.

[32] Y. A. Kusuma and A. C. A. Bima, "Analisis Potensi Ekspor Hasil Olahan Bonggol Jati di Kabupaten Madiun , Jawa Timur," *J. Media Tek. dan Sist. Ind.*, vol. 7, no. 1, pp. 39–46, 2023.

[33] Y. A. Kusuma, "Pengukuran Kualitas Pelayanan Program Pengungkapan Sukarela (PPS) dengan Metode SERQUAL-HOQ," *J. Rekayasa Sist. Ind.*, vol. 8, no. 2, pp. 1–9, 2023.