QUALITY CONTROL MODEL IN THE SUSTAINABLE COCONUT SUGAR SUPPLY CHAIN (CASE STUDY: SMEs IN INDRAGIRI HILIR DISTRICT, RIAU)

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ABSTRACT

Ant-sugar SMEs are developing in the Indragiri Hilir Regency. This industry uses the sap of hybrid coconut trees to make sugar. To maintain sustainability, SMEs require assistance with quality from upstream to downstream. Based on this, the research attempts to ascertain the mechanism of the sugar supply chain, identify the elements that lead to flaws, and suggest ways to enhance the chain's quality. Identify supply chain conditions using the Vorst method. Identify the root causes of problems using the FTA method and quality improvement proposals based on evaluating potential failure levels using the FMEA method. The research results show that the supply chain members are Farmers, SMEs and Final Consumers. The factors causing defects in coconut sap water and ant sugar are human and environmental. The proposed improvement at the farmer level is that the cracked wood preservative must be measured correctly before taking coconut sap water. In contrast, at the SME level, workers pay attention to the ongoing production process and carry out periodic checks when boiling the sap water so that the maturity level is perfect and stir optimally so as not to cause failure. In the crystallization of ant sugar.

Keywords: *Quality control, supply chain, ant sugar, sustainability, SMEs*

Introduction

Indragiri Hilir Regency in Riau Province is the center of the largest coconut plantation in Indonesia and the largest coconut plantation in the world, with an area of 302,369 hectares [1], [2]. One potential product is ant sugar [3]. The currently sustainable sugar product is ant sugar in the form of ant sugar. It increases practicality in serving because it is easier to package and carry, extends shelf life due to low water content, increases economic value, simplifies the packaging and distribution process, and adds taste [3], [4]. Besides, sugar has health benefits with a lower glycemic index value than other sugars [5], [6].

In the increasingly competitive era of industrialization, all economic actors want to successfully compete in the industry to impact the world of trade positively. Hence, it is essential to improve the quality of ant sugar products through monitoring and quality control to meet consumer standards [7], [8]. Ant sugar produced by farmer groups in Indragiri Hilir Regency, Riau, has problems such as the color of the ant sugar appearing dark and lumps of ant sugar that are too large, which consumers do not like, thus damaging the quality of the ant sugar. It is believed that errors during the kneading process and inferior raw materials for coconut sap may have caused the issue. Products that do not meet standards are called defective products and can cause economic losses, so quality control is needed.

Quality control is a system of activities to ensure constant quality standards according to planned specifications so that the products produced are practical and efficient [9], [10]. Quality control could be an essential preparation that points to making strides in an item's quality and guaranteeing it meets the benchmarks set by a company [11]. It includes examining and improving item quality all through the supply chain. Doing so is expected to increase the overall value creation by understanding the relationship between product, financial and information flow from farmers to the final consumers [12].

Fault tree analysis (FTA), which integrates failure mode and effect analysis (FMEA), can be used in quality control in the supply chain. The Fault Tree Analysis (FTA) method is one of the most popular techniques used to identify and find the causes of production process failures that cause product defects [13], [14], [15], [16]. The advantage of FTA is that it can analyze system failures, look for system aspects related to the primary failure, and identify the causes of product failure in the production process [17]. FMEA is a method for evaluating the possibility of failure of a process, design and system and creating steps to handle it [18], [19], [20], [21]. FMEA analysis errors that occur in work activities by evaluating their severity, occurrence and detection and creating a Risk Priority Number (RPN) [22], [23], [24]. FTA and FMEA are used for comprehensive top-level system analysis to be the right solution to overcome problems. "Quality control in the supply chain can be performed using these two methods.".

This research aims to model the quality control of the ant sugar supply chain in Indragiri Hilir Regency, Riau. The case study will focus on Small and Medium Enterprises (SMEs) operating in the region. The study will use Fault Tree Analysis (FTA), Failure Mode and Effect Analysis (FMEA), and the Supply Chain Analysis Framework Method.

Research Methods

Data collection in this research was obtained from one of the SMEs in Indragiri Hilir Regency-Riau. Data collection includes interview data as data for Fault Tree Analysis (FTA) analysis. This is followed by collecting production data and defective product data and continuing with group discussions to determine severity, occurrence and detection ratings in FMEA analysis. Data processing in this research uses Pareto diagrams to identify types of failure from farmers to small businesses, which often lead to product deviations, error tree analysis (FTA) to identify the root of the problem, and FMEA by prioritizing risks using Quality improvement proposals using analysis methods (FMEA) and 5W+1H. "The flow of the system is presented in Figure 1.

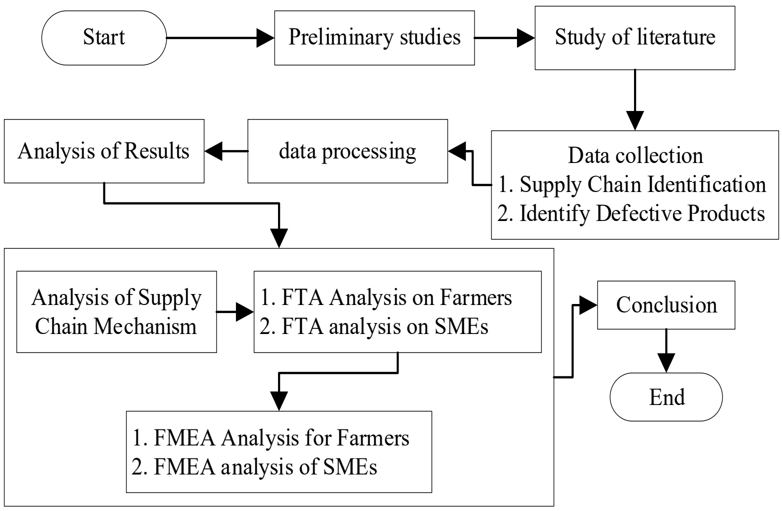

Figure 1. Flowchart of research stages

Data Processing and Analysis Methods

Supply chain identification

The initial step in our research is to identify the supply chain. We have employed descriptive and qualitative methods, supported by practitioner opinions, field observations, and literature reviews, to identify the supply chains. Using the Vorst framework [25]. According to Vorst's (2006) approach to identifying supply chains, four principal frameworks are considered necessary. The structure of the chain, the scope of the chain and the roles of its members, as well as the agreements that form the chain, are as follows:

1. A chain business process is a structured and measurable series of business activities that achieve specific results for consumers.
2. Network and chain management describes the coordination of members to carry out processes in a supply chain.

3. Chain resources are used to produce and deliver products to consumers.

Identification of defective products

We identified the types of defects that occurred from November to February. Next, a Pareto diagram is created, which is a diagram to identify the causes of problems and the consequences that occur. This diagram can be used to identify the causes of errors that have the main impact of the error. Analyze the results of the Pareto diagram to identify the leading causes of errors that occur so that we can implement improvement plans.

Determination of Cause of Failure

It determines the cause of failure with Fault Tree Analysis (FTA). The FTA phase defines the problems and limitations of the product manufacturing process, creates tables that classify the production process and product quantities, and creates a fault tree. Next, identify the problem that caused the product to fail and create a fault tree.

Development of Effect Analysis Model

Failure Mode and Effect Analysis (FMEA) evaluates potential errors in a system, design, process, or service and develops procedures to correct these errors. FMEA quantifies all possible errors and determines processing priorities [26]. FMEA is a robust risk assessment method that categorizes errors based on results. The severity of errors is rated from 1 to 10. Risks can be minimized or eliminated in a company's design, production, and service stages [27]. FMEA is used to define, identify and resolve errors and problems in the production process, both known problems and potential problems that occur in the system as follows [28]:

1. Determine the Severity Value
   The Severity level is used to identify the potential impact of a bug with the lowest level of severity or risk, with a rating of 10 being the highest level of severity or risk, as shown in Table 1.
2. Determine the Occurrence Value
   An event means that this cause may occur during the product's life and lead to failure. Frequency ranking is determined from ranks 1 to 10. As can be seen in Table 2, rank 1 is a low or rare occurrence, and rank 10 is a high or frequent occurrence.
3. Determine the detection value
   Detection is a step to prevent the failure of a service, process, or customer; it is also called testing or analysis. When determining the detection order, there are ratings from 1 to 10. Rank 1 is a control level that can (always) detect errors, and rating 10 is a control level that cannot detect errors.
4. Calculate the RPN value
   RPN (Risk Priority Number) is an approach that multiplies the values of Severity, Occurrence, and Detection to determine priority actions.

$$RPN = \textit{Severity}\ (S) \times \textit{Occurrence}\ (O) \times \textit{Detection}(D) \qquad (1).$$

Table 1. Determining Severity Values

Rantings	Information
1	The form of failure has an impact
2	There was a minor disruption to the production line
	Product specifications do not match but are acceptable
	Attentive customers notice defects
3	Minor damage to the production line
	Product specifications do not match but are acceptable
	Some customers noticed defects
4	Minor damage to the production line
	Product Specifications Disagree but Accepted
	Agreed, the defect is generally known to the customer
5	Minor disruption to the production line
	Product specifications do not match but are acceptable
	These defects are generally known to customers
6	There was a minor disruption to the production line
	This defect does not affect further processing
7	Production can run but does not meet specifications

Rantings	Information
	There was a minor disruption to the production line
	The error affects one subsequent process
	The product becomes waste in the following process
	There was a minor disruption to the production line
8	The defect affects two processes
	The product becomes waste in the following process
9	Mistakes quickly become futile
	An error occurred with the warning
10	Mistakes quickly become futile
	The error occurred without prior warning

Table 2. Determining Occurrence Values

Ratings	Criteria
1.2.3 and 4	Low severity failure
5 and 6	Occasional failure
8 and 7	Repeated failure
9 and 10	Failure is very high and irreversible

Table 3. Determining the detection value

Ratings	Criteria
1	100% of control tools can detect errors and function properly
2	85-90% of control devices can detect errors and function properly
3	80-85% of control devices can detect errors and function properly
4	70-80% of controllers can detect errors and function normally
5	65-70% of control devices can detect errors and function properly
6	60-65% of control devices can detect errors and function properly
7	30-50% of control devices can detect errors and function properly
8	20-30% of controllers can detect errors and function normally
9	0-20 % controller detects errors and functions correctly.
l0	No errors detected

Results and Discussion

Identification of Supply Chain

The results of the supply chain identification questionnaire were obtained from the participants in this study. The table of the supply chain identification questionnaire is in Table 4. The supply chain network involves multiple actors or parties from upstream to downstream [29]. The structure of the ant sugar supply chain has been identified as follows: farmers act as collectors of coconut palm juice, and SMEs act as producers and consumers, as shown in Figure 2.

Table 4. Questionnaire of Supply Chain Identification

No	Question	Answer
1	Who are the members, and what are their roles?	Coconut Palm Farmers, SMEs, Consumers
2	How are the rules configured?	Using a contract system
3	Who are the business actors and processes in SCM?	Farmers and SMEs
4	How is the integration of each process?	The integration used is very structured
5	What management structure is used?	Farmers, SMEs, consumers
6	How is the contract binding?	Wholesale system
7	What resources are used?	Man, Machine

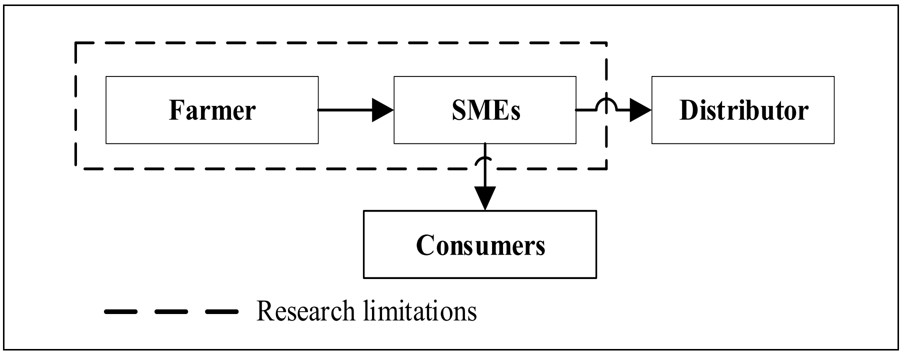

Figure 2. depicts the structure of the supply chain for ant sugar

Identify defective products in the supply chain.

The defective product at the farmer level is coconut sap. The total production of coconut sap water was 1880 liters, with a defective amount of coconut sap water of 250 litres, while the defective product at the SMEs level was ant sugar. The total production of ant sugar is 400 kg, with the number of defects in ant sugar being 30 kg, as shown in Table 6.

Table 5. Coconut Juice Defect Products

No	Month	Production Amount (Liter)	Defect Amount (Liter)
1	November	460	60
2	December	477	50
3	January	474	73
4	February	469	67
Total		1880	250

Table 6. Ant Sugar Defect Products

No	Month	Production Amount (Kilogram)	Number of Defects (Kilogram)
1	November	100	10
2	December	100	7
3	January	100	5
4	February	100	8
Total		400	30

Quality Control Model and Improvement Proposals

1. FTA Analysis for Farmers

FTA analysis data for coconut farmers is coconut sap water, as seen in Figure 3. The analysis results using FTA (Fault Tree Analysis) in Figure 4 show that human factors and environmental factors cause defects in coconut sap water. The human factor (workers) usually needs to pay attention to every step in applying the preservative composition to coconut sap, resulting in the sap becoming rotten or damaged. Environmental factors include the large number of animals that enter the coconut sap water reservoir and the soft natural wood that cannot be filtered.

2. FTA analysis on SMEs

FTA analysis data on small and medium enterprises, especially formate sugar products, is presented in Figure 4. The analysis results using Fault Tree Analysis (FTA) in Figure 4 show that human factors, mechanical factors, and other factors cause all saccharide defect problems. Material. These factors are: a. The human factor (workers) are usually not focused on paying attention to time during the process and are lazy about waiting for prolonged boiling and oven times, causing ant sugar production to experience defects in water content, brown color and experience clumping. b. Environmental factors, namely the room used is not clean, so it is mixed with small dirt.

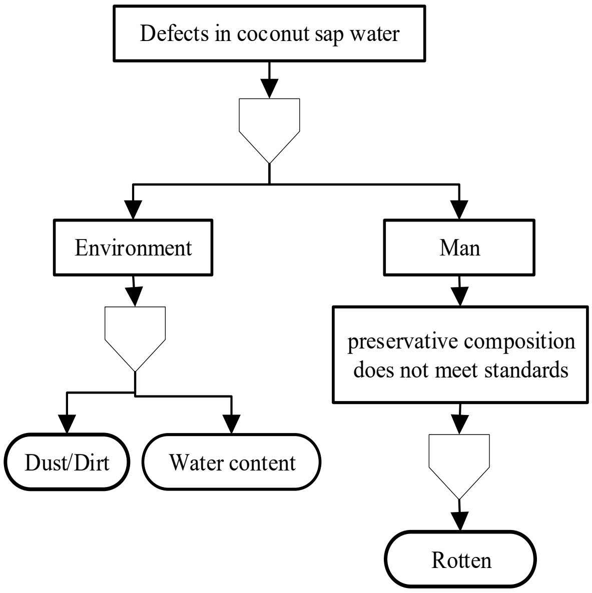

Figure 3. FTA analysis of coconut sap water

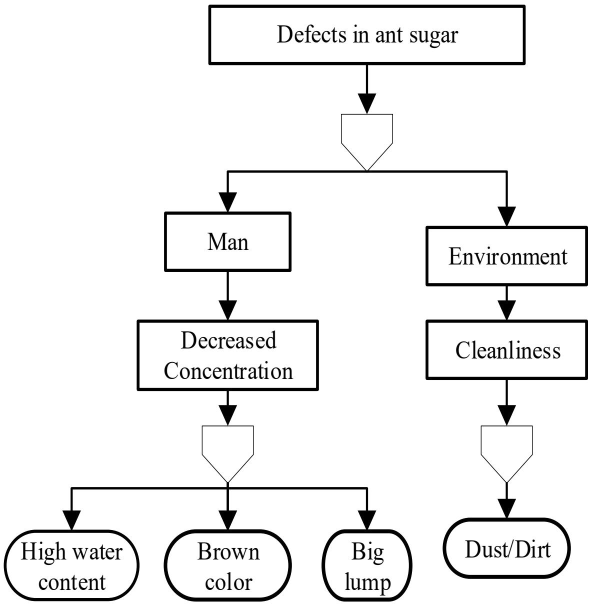

Figure 4. FTA analysis of ant sugar

3. FMEA analysis and proposed improvements

Tables 7 and 8 show the results of FMEA analysis of coconut sap water and ant sugar. RPN values are determined based on the FMEA (Failure Mode And Effect Analysis) data analysis in descending order of magnitude. The FMEA analysis of the coconut sap water revealed that the defective product with the highest RPN value is rotten coconut sap water with an RPN value of 240. The formate sugar produced from damaged coconut sap water can cause the product to malfunction. The FMEA analysis of ant sugar with the highest RPN value showed that most of the ant sugar is either too large or below standard, with an RPN value of 320. Improvements need to be made based on the FMEA RPN analysis results to reduce this error. Tables 9 and 10 present the corrective suggestions for errors related to coconut sap water and ant sugar using the 5W+1H analysis. After analyzing the 5W+1H data, farmers need to measure the preservative, break the wood properly, and arrange it correctly using a spoon to avoid defects in the coconut juice. The sap water is boiled periodically and stirred vigorously during the crystallization of the palm sugar to prevent errors and ensure perfect ripeness.

Table 7. FMEA Analysis of Coconut Sap Water

Failure Mode	**Failure Mode Effects**	**Cause of Failure Mode**	***Severity Rating***	***Occurance Rating***	***Detection Rating***	**RPN**
Coconut sap water	Man	Rotten	10	6	4	240
	Environment	Dust/dirt	7	2	2	28
		Water content more than 85.62%	6	3	10	180

Table 8. FMEA analysis of ant sugar

Failure Mode	**Failure Mode Effects**	**Cause of Failure Mode**	***Severity Rating***	***Occurrence Rating***	***Detection Rating***	**RPN**
Ant Sugar	Man	Dark brown	9	4	4	144
		Big lump	10	8	4	320
		Water content more than 3%	6	2	4	48
	Environment	Lots of dust/dirt	6	5	3	90

Table 9. 5W+1H Analysis of Proposed Repair of Coconut Juice Water Defects

		What	**Why**	**Where**	**When**	**Who**	**How**
Type of defect	Causative factor	What is the improvement plan?	Why do repairs need to be made?	Where are these repairs carried out?	When will the repairs be carried out?	Who is the PIC in repairs?	How to make these repairs?
Coconut sap water	Preservative composition does not meet standards	Measuring preservatives according to standards	So that it is appropriate to measure the coconut sap water preservative	Improvements are made when measuring preservatives	Improvements are made according to the time the coconut sap is collected	Coconut sap farmer	Before collecting coconut sap water, farmers must measure the preservative and cracked wood correctly and use a spoon to make sure it fits properly

Table 10. 5W+1H Analysis of Proposed Improvement of Ant Sugar Defects

		What	Why	Where	When	Who	How
Type of defect	Causative factor	What is the improvement plan?	Why do repairs need to be made?	Where are these repairs carried out?	When will the repairs be carried out?	Who is the PIC in repair?	How to carry out this repair?
Ant sugar (lumps too big)	Insufficient or excessive level of doneness and less than optimal stirring	Improving the quality of cooking properly so that the water content is low and stirring optimally	So that the quality of the ant sugar is good	"The ant sugar SME carried out some improvements."	During the production process, production takes place	Ant sugar SME	Workers pay attention to the ongoing production process and carry out periodic checks when boiling the sap water so that the level of maturity is perfect and stir optimally so as not to cause failure in the crystallization of the ant sugar

Managerial Implications

This research is a quality control model that can help resolve significant problems at one of the SMEs in Indragiri Hilir Regency-Riau, especially in the ant sugar supply chain so that this SME can be sustainable. The main problem is the existence of defective products. Directed problem solving begins with identifying the ant sugar supply chain and continues with identifying the causes of defects and analyzing errors that occur in work activities by distributing the level of severity, occurrence and detection as well as creating a Risk Priority Number so that. It is hoped that solving this problem can help SMEs to reduce production defects thereby increasing added value so that SMEs can be sustainable.

Conclusion

This research has produced supply chain mechanisms and quality control models, as well as suggestions for improving ant sugar at the farmer and small business level. The ant sugar supply chain mechanism consists of supply chain members, namely farmers, small and medium businesses, and consumers. The supply chain mechanism starts from the upstream part, namely coconut farmers, and the downstream part consists of the SMEs themselves. Quality Control is carried out between SMEs and farmers. Analysis using fault tree analysis revealed the factors causing defects in coconut sap water and ant sugar, namely human and environmental factors. Improvements that can be made to carry out the process of repairing defects in RPN-based coconut sap water and ant sugar include providing the correct dose of resak wood as a preservative when harvesting coconut sap, as well as ensuring the correct dosage. Stir and make sure the ant sugar is completely cooked to avoid crystallization. In further research, it is necessary to continue with the creation of an application in the form of a decision support system so that if there are production defects it can speed up decision making for SMEs to improve quality.

References

[1] BPS-Statistics of Indragiri Hilir Regency, *Indragiri Hilir Regency in Figures 2023*, vol. 13, no. 1. 2023.

[2] S. Wardah, Marimin, W. Sudarwati, and U. Marfuah, "Integration of scor and fuzzy ahp for location selection of edible white copra agro-industry integrasi scor dan fuzzy ahp untuk pemilihan lokasi agroindustri kopra putih konsumsi," *J. Teknol. Ind. Pertan.*, vol. 33, no. 3, pp. 216–227, 2023.

[3] S. Wardah and A. Hilda, "Model Rantai Pasok Dan Nilai Tambah Gula Semut Kelapa (Studi Kasus: Kelompok Tani)," *J. Teknol. Agro-Industri*, vol. 9, no. 1, pp. 1–8, 2022, doi:

10.34128/jtai.v9i1.145.

[4] B. Nurhadi, V. A. Maidannyk, M. Djali, E. Herlina Dwiyanti, N. Putrinda Editha, and M. Febrian, “Physical and functional properties of agglomerated coconut sugar powder and honey powder using polyvinylpyrrolidone as a binder,” *Int. J. Food Prop.*, vol. 25, no. 1, pp. 93–104, 2022, doi: 10.1080/10942912.2021.2023177.

[5] S. Wardah, N. Nurhasanah, and W. Sudarwati, “Integration models of demand forecasting and inventory control for coconut sugar using the ARIMA and EOQ modification methods,” *J. Sist. dan Manaj. Ind.*, vol. 7, no. 2, pp. 127–138, 2023, doi: 10.30656/jsmi.v7i2.6500.

[6] S. Wardah and M. Yani, “Spatial-based multicriteria decision-making model for coconut sugar agro-industry location selection: A case study at Indragiri Hilir District, Riau Province, Indonesia,” *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1063, no. 1, 2022, doi: 10.1088/1755-1315/1063/1/012041.

[7] Suharyanto, R. L. Herlina, and A. Mulyana, “Analisis Pengendalian Kualitas Produk Waring Dengan Metode Seven Tools Di Cv. Kas Sumedang,” *J. TEDC*, vol. 16, no. 1, pp. 37–49, 2022.

[8] R. Ratnadi and E. Suprianto, “Pengendalian Kualitas Produksi Menggunakan Alat Bantu Statistik (Seven Tools) Dalam Upaya Menekan Tingkat Kerusakan Produk,” *J. Indept*, vol. 6, no. 2, p. 11, 2016.

[9] W. Ridwan, R. Widiastuti, and E. Nurhayati, “Analisis Pengendalian Kualitas Bibit Sawit Dengan Menggunakan Metode Fault Tree Analysis (FTA) dan Metode Failutre Mode Effect Analysis (FMEA) di PT. Kapuas Sawit Sejahtera,” *Reslaj Relig. Educ. Soc. Laa Roiba J.*, vol. 5, no. 6, pp. 3730–3738, 2023, doi: 10.47467/reslaj.v5i6.2741.

[10] S. Wardah, S. Suharto, and R. Lestari, “Analisis Pengendalian Kualitas Proses Produksi Produk Nata De Coco Dengan Metode Statistic Quality Control (Sqc),” *JISI J. Integr. Sist. Ind.*, vol. 9, no. 2, p. 165, 2022, doi: 10.24853/jisi.9.2.165-175.

[11] A. Wicaksono, E. Dhartikasari Priyana, and Y. Pandu Nugroho, “Analisis Pengendalian Kualitas Menggunakan Metode Failure Mode and Effects Analysis (FMEA) Pada Pompa Sentrifugal Di PT. X,” *J. Tek. Ind. J. Has. Penelit. dan Karya Ilm. dalam Bid. Tek. Ind.*, vol. 9, no. 1, p. 177, 2023, doi: 10.24014/jti.v9i1.22233.

[12] M. D. Pangestuti, M. Mukson, and A. Setiadi, “Analisis Rantai Pasok Pemasaran dan Nilai Tambah Gabah di Kecamatan Undaan Kabupaten Kudus,” *J. Ekon. Pertan. dan Agribisnis*, vol. 3, no. 4, pp. 671–680, 2019, doi: 10.21776/ub.jepa.2019.003.04.2.

[13] J. Haekal, “Quality Control with Failure Mode and Effect Analysis (FMEA) And Fault Tree Analysis (FTA) Methods: Case Study Japanese Multinational Automotive Corporation,” *Int. J. Sci. Adv.*, vol. 3, no. 2, pp. 227–234, 2022, doi: 10.51542/ijscia.v3i2.14.

[14] M. Yazdi *et al.*, “Fault tree analysis improvements: A bibliometric analysis and literature review,” *Qual. Reliab. Eng. Int.*, vol. 39, no. 5, pp. 1639–1659, 2023, doi: 10.1002/qre.3271.

[15] F. Ikwan, D. Sanders, and M. Hassan, “Safety evaluation of leak in a storage tank using fault tree analysis and risk matrix analysis,” *J. Loss Prev. Process Ind.*, vol. 73, no. January, p. 104597, 2021, doi: 10.1016/j.jlp.2021.104597.

[16] M. Kumar and M. Kaushik, “System failure probability evaluation using fault tree analysis and expert opinions in intuitionistic fuzzy environment,” *J. Loss Prev. Process Ind.*, vol. 67, p. 104236, 2020, doi: 10.1016/j.jlp.2020.104236.

[17] A. Anwardi and Y. Pratama, “Perbaikan Efektivitas Pekerja Menggunakan Overall Labour Effectiveness dan Fault Tree Analysis Studi Kasus: PT. Riau Graindo Dumai,” *J. Tek. Ind. J. Has. Penelit. dan Karya Ilm. dalam Bid. Tek. Ind.*, vol. 4, no. 1, p. 64, 2018, doi: 10.24014/jti.v4i1.5725.

[18] A. N. Fuad and A. W. Risqi, “Critical Component Analysis Of Amc 36-800 / Ma An Shan Lathe Using Failure Mode And Effect Analysis And Fault Tree Analysis Methods,” *J. Tek. Ind. J. Has. Penelit. dan Karya Ilm. dalam Bid. Tek. Ind.*, vol. 10, no. 1, pp. 27–34, 2024.

[19] M. H. Aiman and M. Nuruddin, “Analisis Kecacatan Produk Pada Mesin Pemotongan Dengan Menggunakan Metode FMEA di UD. Abdi Rakyat,” *J. Tek. Ind. J. Has. Penelit. dan Karya Ilm. dalam Bid. Tek. Ind.*, vol. 9, no. 2, p. 577, 2023, doi: 10.24014/jti.v9i2.23835.

[20] C. Sriliasta Bangun, A. Maulana, R. Rasjidin, and T. Rahman, “Application of SPC and FMEA Methods to Reduce the Level of Hollow Product Defects,” *J. Tek. Ind.*, vol. 8, no. 1, p. 2022, 2022.

[21] I. A. Bayu Nirwana, A. W. Rizqi, and M. Jufryanto, “Implementasi Metode Failure Mode Effect and Analisys (FMEA) Pada Siklus Air PLTU,” *J. Tek. Ind. J. Has. Penelit. dan Karya Ilm. dalam Bid. Tek. Ind.*, vol. 8, no. 2, p. 110, 2022, doi: 10.24014/jti.v8i2.19369.

[22] H. A. Yasin and R. P. Sari, “Pengembangan Sistem Inspeksi Digital Berbasis Macro VBA Excel

Dengan Metode Failure Mode And Effects Analysis (FMEA) (Studi Kasus di PT. Meidoh Indonesia)," *J. Tek. Ind. J. Has. Penelit. dan Karya Ilm. dalam Bid. Tek. Ind.*, vol. 7, no. 1, p. 7, 2021, doi: 10.24014/jti.v7i1.11322.

[23] E. Ungvári, I. G. Gyurika, and T. Csiszér, "Evaluation of the failure effects of a screwing station using a new approached FMEA," *MethodsX*, vol. 11, no. July, pp. 1–9, 2023, doi: 10.1016/j.mex.2023.102278.

[24] H. C. Wahyuni, M. A. Rosid, R. Azara, and A. Voak, "Blockchain technology design based on food safety and halal risk analysis in the beef supply chain with FMEA-FTA," *J. Eng. Res.*, no. December 2023, 2024, doi: 10.1016/j.jer.2024.02.002.

[25] J. G. A. J. VAN DER VORST, "Performance measurement in agri-food supply-chain networks," *Quantifying Agri-Food supply Chain*, pp. 15–26, 2006, doi: 10.1007/1-4020-4693-6_2.

[26] S. Andiyanto, A. Sutrisno, and C. Punuhsingon, "Penerapan Metode FMEA (Failure Mode And Effect Analysis) Untuk Kuantifikasi Dan Pencegahan Resiko Akibat Terjadinya Lean Waste," *J. Online Poros Tek. Mesin*, vol. 6, no. 1, pp. 45–57, 2017.

[27] A. Anastasya and F. Yuamita, "Pengendalian Kualitas Pada Produksi Air Minum Dalam Kemasan Botol 330 ml Menggunakan Metode Failure Mode Effect Analysis (FMEA) di PDAM Tirta Sembada," *J. Teknol. dan Manaj. Ind. Terap.*, vol. 1, no. I, pp. 15–21, 2022, doi: 10.55826/tmit.v1ii.4.

[28] G. Al Ghivaris, K. Soemadi, and A. Desrianty, "Usulan Perbaikan Kualitas Proses Produksi Rudder Tiller Di PT . Pindad Bandung," vol. 03, no. 04, pp. 73–84, 2015.

[29] N. D. Satmoko, H. Hersusetiyati, M. D. Priadi, and Y. Yuniarsih, "Manajemen Rantai Pasokan Pada Kegiatan Kewirausahaan Dan Inovasi Produk Sebagai Penentu Kinerja Ukm," *JISIP (Jurnal Ilmu Sos. dan Pendidikan)*, vol. 7, no. 1, pp. 383–388, 2023, doi: 10.58258/jisip.v7i1.4287.