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Application of Cleaner Production in a Fruit Chips Industry

Penerapan Cleaner Production *di Industri Keripik Buah*

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Abstract

Cleaner production (CP) is one of the sustainable implementations of a comprehensive preventive environmental strategy involving company processes, products, and services. CP plan implementation still faces obstacles, such as the lack of detailed information, tools, and techniques. This study aimed to determine the variables and to select alternative solutions for cleaner production at a fruit chip industry using the Analytical Hierarchy Process (AHP) method. The research was carried out at PT Agrijaya Indotirta in Malang, East Java. The production process at this company generates waste from the consumption of energy, water, materials, and raw materials. Energy and water consumption are disposed directly without preliminary recycling process. Used oil is sold, and the remaining fruit seeds are sold for seeds. Checklists are used for problem identification, while fishbone diagrams and the 5W1H method are used to solve the problem of getting the best solution from the available alternatives. The weighting results of the alternative solutions using the AHP method show that the application of Good Manufacturing Practice (GMP) (with a weight of 0.287080) on the human resource criteria (with a weight of 0.63699) is a suitable alternative solution for the CP application of fruit chips production at PT Agrijaya Indotirta. Cleaner production can be performed by improving the capacity of human resources as production actors and regulators of proper waste management.
Keywords: Analitycal Hierarchy Process, cleaner production, fruit chips, waste handling

Abstrak

Salah satu implementasi berkelanjutan dari strategi lingkungan preventif komprehensif yang melibatkan proses, produk, dan layanan perusahaan adalah penerapan cleaner production *(*CP*). Implementasi rencana* CP *masih menghadapi kendala, seperti informasi yang kurang rinci, alat, dan teknik. Tujuan penelitian ini untuk menentukan variabel dan pemilihan alternatif solusi* cleaner production *pada produksi keripik di sebuah industri keripik buah dengan menggunakan metode* Analitycal Hierarchy Process *(*AHP*). Penelitian dilakukan di PT Agrijaya Indotirta, Malang, Jawa Timur. Proses produksi pada perusahaan tersebut menghasilkan limbah dari konsumsi energi, air, material, dan bahan baku. Konsumsi energi dan air dibuang langsung tanpa daur ulang. Material berupa minyak dijual dan sisa bahan baku berupa biji buah dijual untuk bibit. Identifikasi masalah dilakukan menggunakan daftar periksa, sedangkan pemecahan masalah dilakukan menggunakan diagram* fishbone *dan metode* 5W1H *untuk memperoleh alternatif solusi. Hasil penilaian bobot alternatif solusi dengan metode AHP menunjukkan bahwa penerapan* Good Manufacturing Practice *(*GMP*) (dengan bobot 0,287080) pada kriteria sumber daya manusia (dengan bobot 0,63699) merupakan alternatif solusi yang sesuai untuk aplikasi* CP *produksi keripik buah di PT Agrijaya Indotirta.* Cleaner Production *dapat dilakukan dengan cara peningkatan peran sumber daya manusia sebagai pelaku produksi dan sebagai pengatur penanganan limbah yang tepat.*
Kata kunci*:* Analitycal Hierarchy Process*, cleaner production, keripik buah, penanganan limbah*

INTRODUCTION

The food industry plays an essential role in the Indonesian economy. One of the most developed small and medium enterprises (SMEs) is chips SMEs, especially tourism (Sari & Roza, 2017). Malang City is one of the tourist cities and the largest chips producer in East Java Province, with fruit chips as its typical souvenirs. Other specific Malang food businesses, such as the ones that sell *dodol* and strudel cake, are competitors for the fruit chip business. The production of fruit chips

causes some environmental problems that needed more concern. The accumulation and intensity of pollutants negatively affect environmental pollution (Zein, Lestari, & Aru, 2019). Waste in large quantities is directly discharged into the environment without any treatment, which leads to the environmental pollution (Michael et al., 2013).

Fruit chip SMEs must manage waste properly to create a green industry because every activity in the production process will produce by-products that impact the environment (Suhardi, Laksono, & Fadhilah, 2017). One alternative to deal with environmental impacts is the concept of cleaner production (CP). CP is a comprehensive and preventive environmental management strategy that is continuously implemented to the production process and to the product life cycle to reduce the impact on the environment and humans (Ujianti, 2017).

The concept of CP has been adopted by many economic, environmental, and social welfare activities to provide zero-waste solutions (Lopes Silva et al., 2013). The main principle of CP in the national clean production policy is applied by rethink, reuse, reduce, recovery, and recycle (5R) (Fadilah, Sunarsih, & Faisya, 2014). CP proposes a broader, integrated, and systematic approach because it includes changes and continuous improvement in all aspects of the organization related to production and processes, which are also the goals of quality control management (Novita et al., 2010). This study aimed to determine the variables and select the alternative solutions for the chips cleaner production at a fruit chip industry.

METHODS

The research was conducted at PT Agrijaya Indotirta, Malang, East Java. The data used are qualitative and quantitative primary data and secondary data. The research stage is presented in Figure 1.

Assessment of Cleaner Production Application

The research method at this stage is observation and interviews with an assessment using a cleaner production checklist (Ariyanti, Purwanto, & Suherman, 2014; International Labour Organization, 2013; Avşar & Demirer, 2008). The cleaner production checklist contains the main aspects and activities related to CP application. Fruit chip production activities generally include sorting, peeling, washing, cutting, cooling, frying, draining, packaging, machine maintenance, and waste treatment. The checklist point functions to focus on the point where clean production must be applied (Sirait, Noor, & Ismayana, 2019).

The cleaner production checklists are shown in Table 1. Checklist points are filled in the "YES" and "NO" columns for each activity. The checklist point in the "yes" column means that the activity has implemented the CP concept and the checklist point in the "no" column means that the activity has not implemented the CP concept. The percentage of each aspect is then calculated to determine the aspect that contributes the most to the company's environmental waste pollution problem (Suhardi et al., 2017).

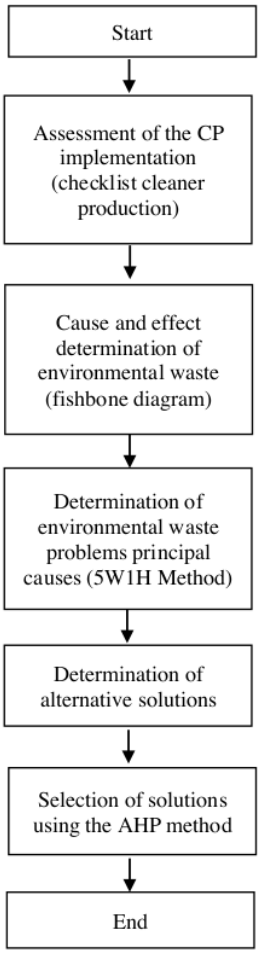

Figure 1. Flowchart of Research Method Framework

Table 1. Cleaner production checklist

Main Aspect (Variable)	Sub Variable	Reference	Observed Activities
Human resources role	Human resources knowledge about CP Production error prevention Employees' implementation of Standard Operating Procedure (SOP) Human resource efficiency	(International Labour Organization, 2013)	Sorting Peeling Washing Cutting Cooling Frying Draining oil Packaging Machine maintenance Waste treatment
Energy used in general	Heater / cooler efficiency Air and lighting efficiency Tool and machine energy efficiency Reused energy	(Suhardi et al., 2017) (International Labour Organization, 2013).	
Water used in general	Cooler's water efficiency Sanitary water efficiency Drainage check Reused water	(Suhardi et al., 2017) (International Labour Organization, 2013).	
Materials and chemicals used in general	Raw materials selection Environmentally safe material use Material waste reduction Use of food-grade standard tool	(Suhardi et al., 2017) (International Labour Organization, 2013).	
Pollution and waste prevention in general	Waste reuse Waste utilization with added value Safe waste disposal Waste reduction measures	(Suhardi et al., 2017) (International Labour Organization, 2013).	

Table 2. Examples of cause categories using fishbone diagrams

Cause Category	Example of Primary Cause Cleaner Production Problem
Man	Lack of skills and knowledge about clean production
Machine	Machinery and equipment that does not support clean production
Method	Procedures are not standard and conflict with clean production
Material	The raw materials quality f standard and negatively impacts the environment
Environment	Unclean workstations, poor air quality, and other environmental aspects that affect clean production

Source: Suhardi et al. (2017)

Causes and Effects Determination of Environmental Waste Problems

The assessment results of the CP application were then identified using a fishbone diagram (Lopes Silva et al., 2013). The problem cause is determined through discussions with expert respondents: the company owner and the fruit chip production operator PT Agrijaya Indotirta. The identified problems were analyzed using the What, Where, Why, When, Who, and How (5W1H) methods. These problems are categorized based on human, machine, method, material, and environmental aspects. Cause example in each category are shown in Table 2.

Determination of Alternative Solutions

Brainstorming with expert respondents was used to determine the problems alternative solutions. The selection of alternative cleaner production solutions at PT Agrijaya Indotirta was performed based on the Analytical Hierarchy Process (AHP) method priority weights with the rating scale shown in Table 3. The assessment results were then processed using Super Decision software. AHP is a multi-criteria decision-making approach by formulating criteria and alternatives in a hierarchical structure (Saaty, 2008; Srđević, Blagojevic, & Srđević, 2011). Alternative solutions in this study were selected based on technical, economic, and environmental criteria. The alternative solution with the highest weight from the AHP results is chosen as an alternative assessment. The alternative weighting in this study was carried out by expert respondents consist of company owners, production operators, and academics.

Table 3. The importance scale of pairwise comparison (Saaty, 2013)

Scale	Definition	Explanation
1	Equal importance	Two criteria / sub-criteria contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favour one criterion / sub-criterion over another
5	Strong importance	Experience and judgment strongly favour one criterion / sub-criterion over another
7	Very strong importance	One criterion / sub-criterion is favoured very strongly over another
9	Strong importance	The evidence favouring one criterion / sub-criterion over another is of the highest possible order of affirmation
2, 6, 4, 8	Intermediate values between adjacent scale values	-

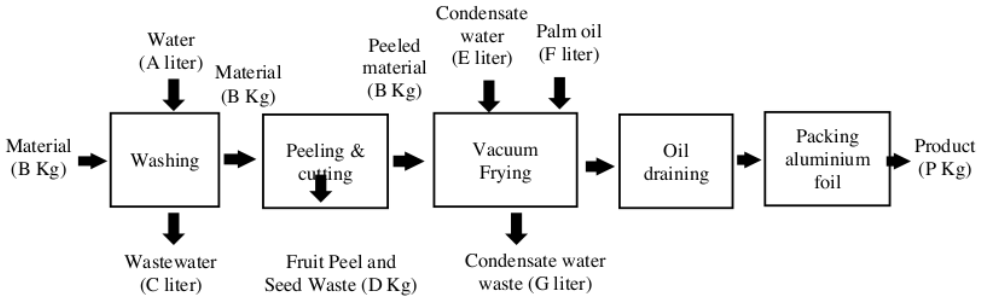

Figure 2. Mass Balance of the Fruit Chips Production

RESULTS AND DISCUSSION

Assessment of Cleaner Production Application

The fruit chips production begins with removing dirt from the fruit by washing. Fruit peel is then removed during the peeling process. The fruit seeds are removed then fruit flesh is cut to produce the desired size. The pieces of fruit flesh are then fried in a vacuum fryer using palm oil. Vacuum frying aims to obtain fruit chip products with better quality, color, texture, aroma, and shelf life (Heruningsih, 2017). The frying takes 50 minutes at a temperature of around 85 °C and air pressure of 70 cmHg (Afrozi, Mufarida, & Sofiyah, 2018). Frying duration, temperature, and air pressure depend on the fruit type. Pineapple chips are fried for 60 minutes at 100 °C with 64-68 cmHg air pressure; *salak* chips are fried for 60 minutes at 77.50 °C with 70 cmHg air pressure; banana chips are fried for 45 minutes at 100 °C with 64-68 cmHg air pressure (Kamsiati, 2010), and mango chips are fried for 60-100 minutes at 80-90 °C with 70 cmHg air pressure (Mufarida, 2019). Condensate water is added in the vacuum frying process as a condenser coolant to condense the water vapor released during the frying process (Wibowo & Nugraha, 2016). The fruit chips from frying were drained using a spinner to reduce the chips' oil content. The fruit chips are then packaged using food-grade aluminum foil packaging. The mass balance for the process of fruit chips production is presented in Figure 2.

The main aspect of the cleaner production checklist includes human resources role, energy used in general, water used in general, materials and chemicals used in general, and pollution and waste prevention in general. The checklist points results based on the CP checklist main aspects at PT Agrijaya Indotirta are shown in Table 4.

Assessment of Environmental Waste Problems Causes

The application of CP in using materials and chemicals has the highest percentage compared to other aspects in general. This high percentage shows that the fruit chip company PT Agrijaya Indotirta has implemented the CP concept in these aspects, such as re-management of discarded water to irrigate plant seeds and utilization of fruit peel and seeds for fertilizer.

Table 4. Recapitulation of CP checklist

Main Aspect (Variable)	Sub Variable	Activities Observed	Yes / No	Activities Involved	Percentage (%)
Human resources role	Human resources knowledge about CP	Sorting (1) Peeling (2) Washing (3) Cutting (4) Cooling (5) Frying (6) Oil draining (7) Packaging (8) Maintenance (9) Waste treatment (10)	No	2, 3, 4, 6, 8, 9	60
	Production error prevention		No	2, 4, 5, 6, 9	20
	Employees' implementation of Standard Operating Procedure (SOP)		Yes	6,7,8	10
	Human resource efficiency		No	2,3,4	10
Energy used in general	Heater / cooler efficiency		Yes	6	20
	Air and lighting efficiency		Yes	5, 6, 7	30
	Tool and machine energy efficiency		No	5, 6, 7	30
	Reused energy		No	6	20
Water used in general	Cooler's water efficiency		Yes	6	20
	Sanitary water efficiency		Yes	3, 9	30
	Drainage check		Yes	9	20
	Reused water		No	3, 9	30
Materials and chemicals used in general	Raw materials selection		Yes	1	10
	Environmentally safe material use		Yes	3,6	40
	Material waste reduction		Yes	10	10
	Use of food-grade standard tool		Yes	6, 7	40
Pollution and waste prevention in general	Waste reuse		Yes	10	25
	Waste utilization with added value		Yes	10	25
	Safe disposal		Yes	10	25
	Waste reduction measures		Yes	10	25

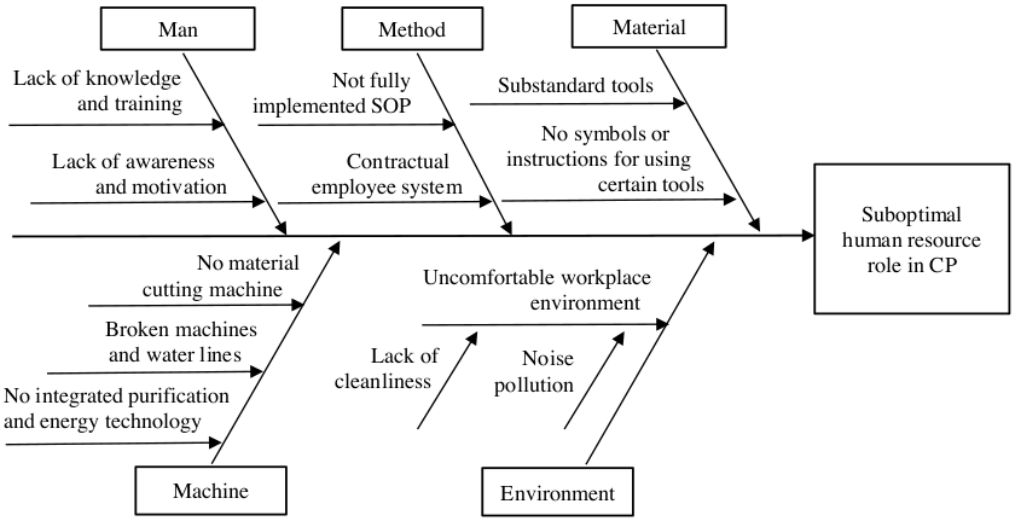

Figure 3. Fishbone Diagram Analysis of Suboptimal Human Resource Role in CP

The aspect that does not apply CP with the most percentage is the human resources role aspect. This statement means that the company has not applied the CP concept to this aspect. A causal analysis diagram (fishbone diagram) was made to identify the problem causes from the discussion results (Fauzi & Defianisa, 2019; Purwani, 2015). Figure 3 shows the results of the discussion.

Table 5. 5W1H on the problem of suboptimal human resource role

Factor	What	Where	Who	When	Why	How
Man	Lack of knowledge and employees training	All workstations	All employees	During the production process	No specific training and recruitment requirements	Design training programs for new and existing employees
	Lack of employees awareness and motivation				There is no CP expert supervising	Recruit experts who can supervise the CP implementation
Method	Not fully implemented SOP	All workstations	All employees	During the production process	Undetailed SOPs and lack supervision	Create sanctions for SOP violation
	Contractual employee system				Contract employees don't fully understand the SOP	Reduce the application of contract work system
Material	There are no specific tool / symbol procedures instructions to simplify the SOP and production process	All workstations	All employees	During the production process	The company does not pay attention to small detail, such as giving symbols / instructions attached to remind employees	Install symbols and SOP instructions to facilitate employees to apply CP
Machine	No material cutting machine	All workstations	The employee in charge of all machines	During the production process	The company is still implementing manual cutting and casual worker	Replace manual cutting tools with automatic cutting tools
	No integrated purification and energy technology				No awareness of water-saving and waste treatment	Implement washing station wastewater purification to be reused for equipment sanitation / maintenance
	Broken machines and water lines				No routine machine checks	Perform routine machine maintenance using SOP
Environment	The workplace environment is not comfortable occurring noise pollution	All workstations	Frying and oil extraction station employees	During the production process	No attempt to reduce the loud machine sound	Provides more soundproof surface and ventilation
	Lack of workplace cleanliness		All workstation employees except packing station		Lack of attention to the work environment cleanliness	Perform routine cleaning and urge the employees to keep the work environment clean

Determination of Suboptimal Human Resource Role in CP Causes and Effects

Human, material, machine, method, and environmental factors are shown in detail using the 5W1H method (Silva, Medeiros, & Vieira, 2017). The purpose of using the 5W1H method is to obtain detailed and targeted alternative improvement solutions (Alpharianto, Suryadhini, & Astuti, 2015). Information about 5W1H in this problem was obtained based on discussions between researchers, product owners, and operators at PT Agrijaya Indotirta (Suhardi et al., 2017). Table 5 shows the discussion results.

Table 5 shows the causes of the problem and the improvement solutions in detail related to the role of human resources at PT Agrijaya Indotirta (Purwani, 2015). The solution obtained from the 5W1H method can be more detailed and varied, so it can be divided into several alternative solutions that are similar and can solve several problems at once based on workstations.

Selection of Alternative Clean Production Solutions

PT Agrijaya Indotirta has limited resources, so the company cannot apply the alternative solutions from the 5W1H method simultaneously. The AHP method evaluates the selected alternatives based on technical criteria, human resources, and the environment. The evaluation and weighting involved three expert respondents who knew the actual conditions of the fruit chip production process. The expert respondents are company owner, production operators, and academics. Alternative solutions from the 5W1H method are then evaluated based on technical criteria, human resources, and the environment to obtain the proposed alternative solutions shown in Table 6. The weighting results on technical criteria, human resources, and the environment are processed using Super Decision software shown in Table 7.

The weighting results using AHP indicate that the criteria for human resources have the

Table 6. Group of alternative solutions from the 5W1H method and proposed alternative solutions

Alternative Solution 5W1H	Alternative Proposed Solution
Design training programs for new and existing employees Recruit experts who can supervise the CP implementation	Apply human resources development & training
Create sanctions for SOP violation Reduce the application of contract work system	Create standard procedures for work system regulations
Provide rewards by giving additional incentives if employees comply with the CP implementation Install symbols and SOP instructions to facilitate employees to apply CP	Create a control map for the implementation of SOP
Replace manual cutting tools with automatic cutting tools to minimize worker errors Implement washing station wastewater purification to be reused for equipment sanitation / maintenance Perform routine machine maintenance using SOP	Create maintenance & equipment replacement schedule
Provides more soundproof surface and ventilation Perform routine cleaning and urge the employees to keep the work environment clean	Apply Good Manufacturing Practice (GMP)

Table 7. The weight value of technical, human resource, and environmental criteria

Criteria	Weight	Rank
Human resource	0.63699	1
Environtment	0.25828	2
Technique	0.10473	3
Total	**1.00000**	

Table 8. Weight rating of alternative solutions

Alternative Solutions	Final Weight	Rating
Apply Good Manufacturing Practice (GMP)	0.387080	1
Create maintenance & equipment replacement schedule	0.203127	2
Create a control map for the implementation of SOP	0.149967	3
Apply human resources development & training	0.136480	4
Create standard procedures for work system regulations	0.123347	5
Total	**1.000000**	

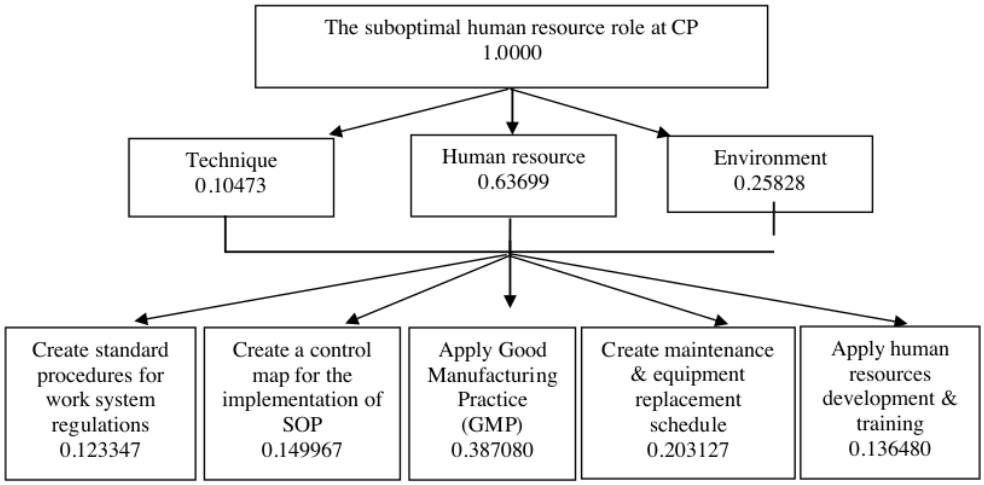

Figure 5. Weight of AHP Method Assessment

highest weight value of 0.63699. This value means that the company must focus on implementing alternative solutions related to human resources. Then evaluate each alternative solution and calculate its weight based on each criterion. The weight of each level in the AHP hierarchy is shown in Figure 5, while the weight ratings of alternative solutions are shown in Table 8.

The application of GMP has the highest alternative solution weight value, which is 0.387080. This value shows that the company must focus on implementing GMP in solving the human resources problem, which is not yet optimal in CP. GMP is one of the guidelines for companies related to food safety aspects, including processes, products, and human resources in applying CP to produce high quality, safe, and suitable food for consumption. The purpose of GMP in CP is to provide basic principles of food safety for companies to produce good quality, safe, and zero-waste food products following consumer demands (Ristyanadi & Hidayati, 2012). Humans as perpetrators of GMP are designed to prevent the emergence of quality problems in a food product caused by chemical, biological, and physical factors (food safety problems). GMP is a basic requirement for companies or food product industries before Home Industry Food certification (PIRT).

The role of human resources in maintaining the safety of fruit chip production at PT Agrijaya Indotirta is in line with the implementation of cleaner production (Ratnawulan, Noor, & Suptijah, 2018). This conformity affects the entire fruit chip processing chain, starting from receiving fresh fruit until the finished product that involves handling waste during production to produce safe, zero-waste products (Fadilah et al., 2014). The application of GMP in the fruit chip industry includes aspects of location, production environment, employees, buildings and facilities, production equipment, water facilities, sanitation activities, employees' health, maintenance procedures, storage, process control, food labeling, supervision of waste management by the person in charge, product recalls, documentation records, and employees staff training (Yulianti & Mustarichie, 2017). All of these aspects involve the human resources of the fruit chip company.

CONCLUSIONS

This study shows that the variables affecting the implementation of CP at PT Agrijaya Indotirta are the role of human resources, the use of energy, water, materials, chemicals in general, and pollution and waste prevention in general. The role of human resources is influential in fruit chip processing in order to produce a safe product and to achieve the target of zero waste. The GMP application was chosen to increase the human resource role in the CP application because it affects the processing, product safety, quality aspects, and waste management. A possible further research can be conducted to analyze the effect of GMP application in the CP application.

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