Scenario Development of Implementing Cleaner Production on Pepper Agroindustry

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Abstract. Smallholder plantations dominate pepper development in Indonesia. In global trade, Indonesia has experienced pepper product detention due to the contamination of microorganisms. It is related to traditional agro-industrial activities that must be improved in quality assurance, hygiene, and food safety. The application of cleaner production is one strategy to overcome this condition. This study aims to analyze the application of a cleaner production approach in the pepper agroindustry. The analysis was performed using Interpretative Structural Modelling (ISM). Cleaner production in the pepper agroindustry is implemented by improving traditional processing systems and mechanical processing applications. The objectives are to increase productivity, process efficiency, and product quality. Both strategies can still be implemented based on conditions in the field. Strategies for improving traditional pepper processing include developing knowledge transfer, enhancing farmer skills, and processing infrastructure and technology provision. The application of machines' processing requires availability and accessibility of technology and support from farmer organizations, financing institutions, and extension programs. The strategy of mechanical processing application begins with strengthening farmer institutions, improving access to finance and financial facilitating by the government, and building stakeholder engagement.

1. Introduction
Quality is an essential issue in the global pepper trade [1]. Intense competition between producing countries and increasing consumer demands encourage farmers to increase pepper production and quality through continuous improvement [2]. Pepper quality is assessed from its physicochemical and microbial parameters [3]. On the other side pepper processing intensely affects the quality and aroma of pepper.

Pepper products traded on the world market are white and black pepper. White pepper is produced through peeling or separating the skin and drying, while black pepper is produced directly through the drying process. Pepper processing is mostly done at the farm level traditionally, consisting of soaking, peeling, washing, and drying. Traditional processing affects pepper quality [4] and raises problems related to time efficiency, labor efficiency, and the potential risk of environmental pollution. Specifically, pepper post-harvest activities can cause environmental problems because the waste generated from the production process has a negative impact on the environment [5]. Improper pepper processing can cause a decrease in the volatile content of pepper and potency water and air pollution. Strategy to overcome by introducing mechanical processing technology [6]. Mechanical processing of white pepper is carried out using the machines of thresher, peeler, dryer and
sorting of pepper, while for black pepper is carried out using machines of pepper thresher, dryer, and blanch. Mechanical pepper processing can improve pepper quality and processing efficiency [7]. However, its implementation at the farmer level is still low due to various obstacles faced.

Improvement of traditional pepper processing is a scenario that can be done if the adoption of mechanical pepper processing cannot be implemented. This study aims to develop scenarios for the application of cleaner production in the pepper agroindustry. The analysis will use the case on white pepper. This study will illustrate how improvements in pepper processing at the farm level can be done by improving the existing processing system or introducing a mechanical processing system.

2. Research method

2.1 Research approach
Cleaner production implementation can be analyzed by using scenarios development. The objective of scenario development is to determine the cleaner production method options based on the ease of implementation, costs and investment, risk and benefits, and the impact on the environment. Analysis used an integrated approach to studying opportunities for implementing cleaner production, including technical, economic, and environmental aspects. The research was carried out by conducting field observation and in-depth interviews.

2.2 Location and time of research
The study was conducted in Bangka Regency (2010 and 2015) and East Luwu Regency (2018), some national white pepper development areas. The information sources are farmer groups and pepper agroindustry units.

2.3 Analysis method
The analysis uses Interpretative Structural Modelling (ISM). ISM used to make decisions in complex situations by connecting and organizing ideas in a visual map. [8]. ISM is modeling that describes the specific relationships between variables, the overall structure, and output in a graphical model in quadrants and variable levels [9]. The steps in implementing the ISM analysis are (1) Identification of variables, (2) Formation of contextual relationships between variables, (3) Development of the Structural Self-Interaction Matrix (SSIM), (4) Formation of Reachability Matrix from SSIM and transitivity checking and (5) Separation of Reachability Matrix in several different levels [10].

3. Result and discussion
The processing of pepper products is mainly carried out at the farm level using simple tools and traditional methods without paying attention to hygiene and food safety factors. Therefore, microorganisms often contaminate the pepper products due to poor collection conditions, conventional processing methods, and drying methods [11]. On the other hand, this practice causes a very high potential for environmental pollution [12].

Consumers today demand on low prices and pay attention to quality, including product safety, hygiene, and health [13] [14]. Consumers want pepper products that have high quality and meet product safety requirements. Product quality can be achieved if pre-harvest and post-harvest handling are carried out properly. Therefore, to get good quality pepper products, it is necessary to pay attention to processing techniques besides factors of cultivation, storage, and marketing techniques.

3.1 Profile of pepper agroindustry
The pepper area in Indonesia reaches 187,291 ha, of which 180,176 ha or 96% are smallholder plantations [15]. The main production centres for pepper in Indonesia are the Bangka Belitung Islands, Lampung, South Sumatra, South Sulawesi, and East Kalimantan Provinces. The contribution of pepper production from the Bangka Belitung is 37.92% of the total national production. Lampung contributed
16.36%, followed by South Sumatra (9.25%), South Sulawesi (7.49%) and East Kalimantan (6.89%), while other provinces contributed 22.08% to the total pepper production in Indonesia [16].

Bangka Regency is one of the pepper centers in Bangka Belitung Province, with 5,162.83 ha and a production of 3,121.50 tons. East Luwu Regency is one of the centers of pepper development in South Sulawesi Province, with 5,710.38 ha and 2,908.37 tons. These two regions produce white pepper. White pepper is pepper produced through the process of peeling or separating the skin and drying. In contrast, black pepper is produced directly through the drying process without going through the process of peeling or separating the skin.

White pepper processing is carried out at the farm level and is dominated by traditional methods, including soaking, washing, separating the skin, drying, sorting, and packaging. After picking, the peppers are put into sacks for soaking. Soaking is carried out for two weeks. The duration of soaking pepper depends on the type or variety of plants, growing environment, fruit maturity, and environmental conditions such as water hardness, or light intensity. After soaking, peeling, and washing, washing and drying are carried out when the outer skin has been peeled off. Drying is done by spreading the pepper, peeled and clean, on a clean mat. The problems that arise from this traditional processing method are related to the quality of pepper and the potential for environmental pollution (Table 1).

**Table 1. Impact of pepper processing with traditional approach**

| Stages of processing | Negative impacts |
|----------------------|-----------------|
| Soaking              | Contamination of water sources |
|                      | The smell of soaking water |
| Separating the skin  | Soil pollution due to solid waste |
| Washing              | Pollution of water sources due to liquid waste |
| Drying               | Air pollution due to pepper skin and dirt on the pepper that blown away by the wind |
| Sorting              | Pollution due to solid waste produced in the form of handles, fibres, and some light pepper |
| Packaging            | Pepper lost |

The traditional pepper processing process has resulted in the emergence of negative impacts on the environment. Contamination of water sources and odors from soaking water is a problem at the immersion stage. Soil contamination due to the remaining unmanaged pepper fruit stripping occurs in the stripping phase. Water pollution occurs due to the flow of residual washing to the water source. Air pollution occurs due to the remaining pepper skin, and dirt on the pepper is blown away by the wind in the drying and sorting phase. While at the packaging stage, the impact is the potential loss of yield.

Spices are susceptible to mold growth and subsequent secondary metabolite production at the harvesting, processing, storage, and handling stage [17]. Improvement of processing methods is a technique to overcome pollution and product quality degradation [18]. The introduction of mechanical white pepper processing has been applied to several production centers. Improvements were made by using a thresher, peeler, dryer, and sorting of pepper. However, this processing technique did not develop massively, related to the need for technical and non-technical support. Therefore, it is necessary to develop scenarios for implementing cleaner production based on regional and farmer conditions.

### 3.2 Cleaner production implementation scenario

The agricultural commodity processing system is related to environmental management strategies to realize sustainable agricultural development. In cleaner production, environmental management is carried out in a preventive, integrated, and sustainable manner in every production process from upstream to downstream, including products and services, increasing the efficiency of using natural resources, and reducing environmental pollution [19]. Thus, cleaner production is a preventive and integrated environmental management strategy applied continuously to the production and product life.
cycle to minimize human and environmental risks [20]. The application of cleaner production benefits sustainably meeting needs by using renewable materials, non-hazardous materials, and using resources efficiently while maintaining diversity. It can minimize risks to human health and safety as well as environmental damage.

Cleaner production can be carried out by reducing raw materials, water, toxic and hazardous materials, and applying environmentally friendly technology, management, and standard operating procedures following established requirements [21]. The application of cleaner production to the pepper agroindustry is possible by improving traditional processing systems and mechanical processing applications. Improvement of the traditional processing system is carried out by increasing the improvement of the processing system at each stage of the process. Improvements are aimed at increasing productivity, process efficiency, and improving product quality. The application of mechanical processing white pepper is carried out using a machine at the threshing, sorting, stripping, drying, and using a soaking tub at the soaking stage.

Comparing the two strategies can be analyzed from the technical, economic, and environmental aspects (Table 2).

**Table 2. The benefit of cleaner production implementation in pepper agroindustry**

| Strategy                     | Technical                  | Economic                                | Environment                           |
|------------------------------|----------------------------|-----------------------------------------|----------------------------------------|
| 1. Improvement of Traditional Processing Systems | Very easy to implement | Provides economic added value in small quantities | Has little effect on the environment |
| 2. Application of Mechanical Processing | Relatively easy to implement but requires particular technical skill | Provides a very significant economic added value | Provides a very considerable effect on the environment |

Mechanical processing of white pepper can reduce contamination of microorganisms that are harmful to health and other impurities such as human, animal and other waste with a shorter processing time. In addition to the main product, farmers can earn additional income by selling by-products (light pepper, groats and dust) as a source of pepper oil. In addition to the above advantages, white pepper processed with these tools has a distinctive pepper aroma, is free from foul odors, and contains high essential oils.

Besides technological aspects, institutional and managerial aspects also affect the implementation and internalization of innovative cleaner technologies [19]. The application of machines’ processing requires availability and accessibility of technology, farmer institutions, and support from supporting institutions, namely financing and extension institutions. Therefore, both strategies can still be implemented based on conditions in the field. In conditions where the availability and accessibility of technology are still low, farmers’ institutions are not running well, and the support of financial institutions and extension services is limited, the traditional processing system improvement strategy can be applied. The analysis procedure can be carried out using the flowchart in Figure 1.
3.3 The strategies of traditional processing improvements

Strategies for improving traditional pepper processing include developing knowledge transfer, enhancing farmer skills, and processing infrastructure and technology provision. Based on the results of the ISM analysis, the scenario for improving traditional pepper processing is shown in Figure 2.

Figure 2. Strategies of improving traditional pepper processing

Description:
E1 = Developing agricultural extension program
E2 = Conducting technical guidance at pepper processing centers
E3 = Strengthening farmer groups
E4 = Developing a community control system through the formation of farmer working groups
E5 = Provision of clean water sources
E6 = Construction of a soaking pool
E7 = Procurement of drying racks
E8 = Provision of waste utilization technology
Improving traditional pepper processing is related to changes in farmers’ knowledge. Therefore the strategy adopted begins with strengthening the transfer of knowledge and understanding of farmers. Initially, the strategy adopted included developing agricultural extension programs, conducting technical guidance at pepper processing centers, and creating a community control system by forming farmer working groups. The next step is to strengthen institutional aspects and provide technology. Afterward, technical steps were taken to encourage the improvement of the production system towards cleaner production.

3.4 The strategies of mechanical processing application

The application of cleaner production in the pepper agroindustry will significantly affect product quality. The product quality stated in the requirements of physicochemical and microbial parameters is expected to be met. The physicochemical parameters were characterized by light berries, dark-colored, moisture, piperine, and essential oil. In contrast, microbial parameters included the number of bacteria, molds and yeasts, and E. coli and Salmonella contamination. The characteristics of pepper produced by machine without soaking or antioxidant treatment and in the traditional approach can be seen in Table 3.

| Characteristic | Traditional processing | Mechanical processing |
|----------------|------------------------|-----------------------|
| Colour         | Yellowish white         | Slightly dark white   |
| Aroma          | Pepper specific, the aroma is not strong enough, the stench still carries over | Pepper specific, more intense aroma, free from bad smell |
| Water content (% v/b) | 11.9                 | 11.7                  |
| Essential oil content (%v/b) | 2.5                   | 3.2                   |

Source: [22]

Mechanical processing applications are not only related to technical issues but also institutional aspects [23]. Management of mechanical processing is carried out by farmer groups which require arrangements at the group level related to the capacity of the processing machine. In addition, the procurement of processing equipment and machinery requires investment. Therefore, the strategy of mechanical processing application begins with strengthening farmer institutions, improving access to finance and financial facilitating by the government, and building stakeholder engagement (Figure 3).

![Figure 3. Strategies of mechanical processing application.](image-url)
Description:
E1 = Strengthening Farmer Institutions
E2 = Improve Access to Finance
E3 = Financial Facilitating by Government
E4 = Developing Geographic Indication
E5 = Developing Future Market
E6 = Developing Warehouse Receipts System
E7 = Provision of Technology
E8 = Developing Technology Transfer System
E9 = Formulating Pepper Development Policy
E10 = Stakeholder Engagement
E11 = Developing Market Information System

The consequence of implementing mechanical processing is the need for investment in the purchase of machines and tools. Financial feasibility performance will be influenced by product marketing capabilities so that the marketing aspect becomes one of the factors related to the sustainability of the mechanical processing implementation strategy. Marketing-related strategies include developing Geographic Indications, developing marketing contracts, and developing warehouse receipts systems.

Geographical Indication is a sign that indicates the area of origin of the product, which due to geographical, environmental factors, gives a particular reputation, quality, and characteristics to the resulting product. Products with Geographical Indications will provide quality assurance to increase consumer confidence.

Pepper is a commodity with relatively high price fluctuations due to the increased production risk in the pepper cultivation system. Commodity Futures Trading is useful for risk management through hedging activities, a means of forming prices, and an alternative investment. Risk management can also be carried out by implementing the Warehouse Receipt System as an activity related to issuing, transferring, guaranteeing, and settlement of Warehouse Receipt transactions. A warehouse receipt is a trading instrument that empowers farmers. The commodity produced can provide economic value in the form of a guaranteed value, which can be used to obtain credit.

Improvements in the agroindustry will be followed by marketing strategies, transferring technology, and developing farmer institutions and marketing information systems development. Thus, the change in pepper processing is not only in installing processing tools and machines but also in building a production system with the support of a profitable marketing system. Thus, changes in pepper processing are not about installing processing tools and machines but also building a production system with the support of a profitable marketing system.

The benefits obtained from the cleaner production implementation are expressed in additional income and improved quality of pepper products. In addition, cleaner production in pepper processing will increase production efficiency and improve natural resources management. From the environmental aspect, cleaner production will maintain land fertility, ecological sustainability, and develop a sustainable production system. Farmers will be encouraged to have a mental attitude responsible for health, safety and environment management. In the end, all of these benefits will facilitate the creation of competitiveness in the global market.

4. Conclusion
Increasing the competitiveness of pepper in the global market can be achieved through the implementation of cleaner production. Implementing cleaner production to the pepper agroindustry is possible by improving traditional processing systems and mechanical processing application. The application of cleaner production will increase production and productivity and increase product quality, including consumption safety. Mechanical processing is carried out using a machine at the threshing, sorting, stripping, drying, and using a soaking tub at the soaking stage. Improvement of the traditional processing system is carried out by improving the processing system at each stage.

The application of processing using machines requires not only technical aspects but also non-technical aspects. In a situation where the availability and accessibility of technology are still low, farmer
institutions are not running well, and financial and extension support institutions are still limited, a strategy for improving traditional processing systems can be applied. Strategies to support the improvement of traditional processing systems are directed at farmers’ knowledge.

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