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ZERO WASTE MANAGEMENT ARABICA COFFEE AS A SUPERIOR PRODUCT IN MAGETAN REGENCY

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ABSTRACT

One of the coffee producers in East Java province in Indonesia is Magetan Regency. The majority of coffee processing industries in the region are small and medium industries. Limited capital, knowledge and technology make them limited in processing waste including coffee pulp. This research aims to analyze the potential for utilizing coffee pulp which can be implemented sustainably by small coffee processing industries and provide additional income. The method used is analytical hierarchy process (AHP) with expert choice software. The most effective use of coffee skin waste for small coffee processing industries is cascara. The results of the mass balance balance analysis in 1,000 kg of Arabica coffee production produced coffee beans with horny skin or coffee with hard skin (HS) with a water content of 5.83% of 283 kg, solid waste 726 kg, coffee processing wastewater 1,613 kg. Cascara showed the highest financial feasibility where an NPV value of IDR 1,368,544,232 was obtained; IRR 52%; B/C Ratio 6.08; and PBP 0.90 or 10 months. The calculation assumes that the production of cascara tea is sold out at an interest rate of 10%.

KEYWORDS: Coffee Processing, Small Medium Industries, Coffee Pulp.

INTRODUCTION

Indonesia is the 4th largest coffee producing country in the world after Brazil, Vietnam and Colombia [1]. The average contribution of coffee to gross domestic product (GDP) was 3.51 percent during 2016-2021, making it one of the leading commodities in the national economy [2] . One of the coffee producing areas in East Java Province is Magetan Regency as seen on Figure 1. Coffee is the 4th leading plantation and horticultural commodity in Magetan Regency as stated in Regional Regulation no. 8 of 2009 concerning Regional Long Term Development Plans 2005-2025.

Arabica coffee is one of the most widely cultivated types. 400 grams of wet coffee pulp is produced from 1,000 kg of fresh berries. Coffee pulps contain protein, fat, minerals, caffeine, tannin and solid organic residues [3]. Coffee processing also produces dregs, husks, coffee pulps and wastewater which, if not managed properly, can pose a serious threat to water and soil pollution [4]. Producers often avoid processing coffee waste because it requires high costs [1].

Figure 1: Coffee processing in Magetan Regency, East Java - Indonesia.

Coffee processing waste must be managed properly based on correct waste management principles to avoid environmental pollution [5]. Reuse of coffee waste can provide more financial benefits [3]. Utilization of coffee waste based on its physical and chemical characteristics and supporting technology is a contribution to sustainable development [1]. Sustainable development is the convergence of the triple bottom line which includes economic development, social justice and environmental protection [6].

Related to this, efforts to improve the quality of life are to minimize the use of natural resources and reduce the use of toxic materials and pollution so as not to endanger the needs of future generations [7].

The zero-waste approach is an effort to manage resources through redesigning the resource chain so that the final product can be reused or recycled [8]. This effort means that final disposal is the last option after prevention, reuse, recycling and recovery in the waste management hierarchy to preserve natural resources and protect the environment [9]. The coffee industry must strive to process by-products resulting from processing through innovative and useful applications to increase process sustainability [10] . Sustainable awareness requires fundamental changes aimed at exploring all aspects of reusing coffee waste.

One way to explore resource efficiency in coffee processing is through the use of coffee production waste, especially coffee pulps. The most appropriate and efficient technology continues to be developed [11]. The uses of coffee pulps include animal feed, compost [12], natural dye [4]. Coffee pulp also contains anti-oxidants which function to neutralize free radicals to prevent various diseases [13]. Utilization of coffee skin waste by small coffee processing industries is a challenge in itself. As is known, small coffee processing industries have limited capital, knowledge and technology. The contribution of small coffee processing industries to environmental preservation in the context of sustainable development needs to be assessed for its technical and financial feasibility. This research aims to analyze the potential for utilizing coffee husk waste which can be implemented sustainably by small coffee processing industries and provide additional income.

2. METHOD

Cleaner production is part of zero waste management which has a high possibility of being applied in small industrial environments processing coffee in a sustainable manner. A small coffee processing industry in Magetan, East Java, Indonesia has initiated cleaner production by utilizing coffee husk waste into animal feed, cascara tea and biogas. This effort needs to be analyzed for its technical and financial feasibility so that it becomes motivation for small coffee processing industries to determine the most profitable management options.

The method used is analytical hierarchy process (AHP) with expert choice software. AHP is a decision support model that describes a complex multi-factor or multi-criteria problem in an objective structure, followed by levels of factors, criteria and so on until the final level [14] . The software automatically carries out an assessment to determine the best alternative while carrying out validation and sensitivity tests on all alternatives. The results that will be obtained are the priority values of each alternative. The materials used are Arabica coffee logs and coffee processing wastewater. The data used in this research are primary data and secondary data.

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Primary data includes mass balance, energy balance, and analysis of wastewater characteristics, as well as questionnaire results. The questionnaire is arranged according to the hierarchy that is formed where each question point will form a pairwise comparison matrix. Determination of expert respondents is determined by judgment sampling where respondents are selected according to the required criteria. The respondents selected were those who knew the coffee agroindustry and consumed the product at least once. Expert sampling of respondents was carried out deliberately (convience sampling). This research also uses secondary data consisting of coffee processing process data, quality standards for coffee wastewater, and cleaner production alternatives in coffee processing.

3. RESULTS AND ANALYSIS

3.1 Mass balance analysis of Arabica coffee processing

Mass and energy balance calculations are based on the law of conservation of mass and energy where energy cannot be created or destroyed but can be converted into other forms [15] . This mass balance analysis was carried out to determine the input and output of post-harvest processing of Arabica coffee. This identification is carried out thoroughly at every step of the process, starting from sorting the fruit, peeling the fruit skin, fermentation, washing and drying. The raw material used is mature Arabica coffee. The Arabica coffee processing process is carried out every harvest with a minimum of 1,000 kg. The mass balance of the Arabica coffee processing process can be seen in Figure 2. The results of the mass balance balance analysis in 1,000 kg of Arabica coffee production produce coffee beans with horny skin or coffee with hard skin (HS) with a water content of 5.83% of 283 kg, solid waste 726 kg, coffee processing wastewater 1,613 kg.

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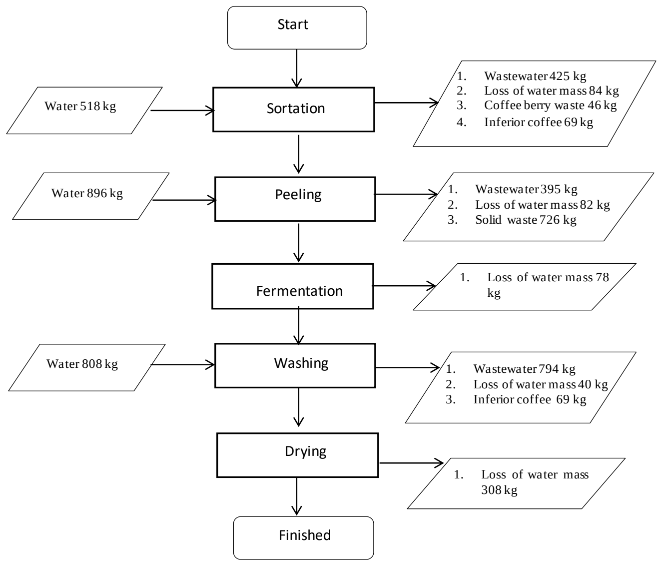

Figure 2: Mass balance diagram of Arabica coffee processing

3.2 Analysis of Arabica coffee processing wastewater pollution

Arabica coffee processing produces solid waste and waste water. The solid waste produced is coffee pulp which comes from sorting the rambang, peeling the skin of the fruit, while waste water comes from sorting the rambang, stripping the skin of the fruit, and washing. Solid waste is used as a base for cascara tea and some of it is thrown into the rice fields, while waste water is thrown directly into the gutter without any prior treatment. Arabica coffee processing wastewater is analyzed to determine the level of pollution and determine appropriate treatment alternatives so that the waste is not dangerous to human health and the environment.

Table 1 is the result of analysis of the characteristics of Arabica coffee processing wastewater and wastewater quality standards. The results of measurements of Arabica coffee processing waste water exceed the maximum quality standards for coffee wastewater set by the Minister of the Environment of the Republic of Indonesia No. 5 of 2014, so the waste must be treated before it is discharged into water bodies or the environment so that it does not harm the surrounding environment. Coffee processing wastewater is produced in the fermentation and washing processes [16]. Coffee processing produces 40-45 liters of wastewater per kilogram of coffee [17]. Coffee processing produces 40-45 liters of waste water per kilogram of coffee. Coffee wastewater has the characteristics of high acidity, tannins, phenols and alkaloids which inhibit biological degradation so that it can pollute water [18] [19].

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Table 1: Results of analysis of the characteristics of Arabica coffee processing wastewater

Parameter	Quality standards	Sortation	Pulping value	Washing	Unit
pH	6-9	5.7	5.7	5.3	-
Total Dissolved Solids	-	5.999	37.096	11.557	mg/L
Total Suspended Solids	150	1.072	3.245	6.542	mg/L
Biological Oxygen Demand(BOD_5)	90	911	3.570	2.216	mg/L
Chemical Oxygen Demand	200	3.715	5.560	3.679	mg/L

3.3 Identify implementation of cleaner production alternatives

This identification is carried out to find out what alternative clean production actions can be implemented according to the conditions and needs at the location, so that an analysis of the problem level of each processing process is carried out. Analysis of the problem was carried out comprehensively from sorting the rambang, peeling the skin of the fruit, fermentation, washing and drying. All impacts of the problems that have been identified can be seen in Table 2. Not all problems and solutions will be followed up. In the sorting process, peeling fruit skin and washing produces waste water, so it is necessary to identify alternative solutions for handling this waste.

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Table 2: Identify problems at each processing step along with solutions and benefits

Processing steps	Problems	Solution	Economic benefit	Environmental benefit	Annotation
Rambang sorting	There are many coffee logs that cannot be produced further because the quality is not suitable	Coffee logs can be processed into animal feed, cascara and biogas	Can reduce animal feed costs	Can reduce the potential for pollution due to waste water from sorting activities	Hasn't been done yet
	A lot of waste such as leaves, stalks and soil sticks to coffee cherries	Leaf waste can be processed into a compost mixture	Can reduce the use of organic fertilizer on other plants	Fertilize the soil	Hasn'tbeen done yet
	Produces quite a lot of waste water from sorting activities	Coffee processing wastewater can be used to water vegetable plants around the production area	Increasing industrial income	Reduce water pollution	Hasn't been done yet
Peeling	There are coffee beans that dissolve along with the coffee pulp coming out	Coffee pulp solid waste can be processed into cascara tea	Optimizing the output of coffee peeling to be used as a commercial product	Can reduce the potential for environmental pollution due to coffee processing wastewater	Hasn't been done yet
	Solid waste is allowed to accumulate around the production area	Coffee pulp can be processed into animal feed	Increasing industrial income	Reducing the use of fossil fuels	Hasn't been done yet
	Waste water is allowed to flow directly into the gutter	Waste water can be collected to be processed into biogas base material	Reducing the use of fossil fuels	Reducing water pollution around production sites.	Hasn't been done yet
Fermentation	There is no special place for the fermentation process (still using sacks)	A place is provided for the Arabica coffee fermentation process	Can improve the quality of fermented material output	Does not damage the environment due to the mucus continuing to flow	Hasn't been done yet
Washed	Waste water is not used but is directly thrown into the gutter	A wastewater treatment plant is needed so that it can be	Reducing the use of fossil fuels	Reducing water pollution around production sites.	Hasn't been done yet

Processing steps	Problems	Solution	Economic benefit	Environmental benefit	Annotation
		processed into biogas			
Drying	The para para used are made of iron so they rust easily	It is necessary to modify the para para by increasing the height of the tool and making it made of stainless steel	Improving the quality of products	Minimize the use of drying areas	Hasn’t been done yet
	Para para can be made from wood but can increase the water content when drying in the morning	There is a need to modify the shape of the panels made from iron and wood	Improving the quality of products	Minimize the use of drying areas	Hasn’t been done yet
	The para-para used is rectangular in shape so only one drying is enough	There is a need to modify the shape of the panels made from iron and wood	Improving the quality of products	Minimize the use of drying areas	Hasn’t been done yet

Based on the results of problem identification and consensus deliberation, there are waste management alternatives that support the implementation of cleaner production. Alternatives include processing coffee pulps as cascara tea products, animal feed and biogas. Coffee pulp waste produced from wet processing has better ingredients but has a high-water content so it does not last long. Adding other feed sources is the best method to improve nutrition and make it last longer [20].

Another use for coffee pulp waste is cascara. Cascara is a drink like tea but has the aroma of coffee. Caffeine extracts, tannins and antioxidants contained in coffee skins have the potential to become bioactive compounds for energy drinks that are beneficial for health [21]. Cascara is made by drying the coffee pulps for 4-5 days until they produce a blackish brown color [22]. Coffee skins can also be used to make biogas with pre-treatment first. The tannins, caffeine and polyphenols in coffee skin waste contain toxic substances for microorganisms so they can inhibit biogas production. Pre-treatments that can be carried out include irradiation and microwaves (physical), ionic liquids and wet oxidation (chemical), as well as enzymatic and fungal (biological). One of the pre-treatment methods is physical and biological by reducing the size of the coffee skin to 35 mesh and using civet droppings. The fermentation process uses cow dung and rumen fluid from microorganisms [23].

3.4 Technical feasibility analysis

The technical feasibility analysis functions to assess the technical suitability applied in the coffee processing industry through its usage capacity, water and energy efficiency, waste minimization and environmental impacts in the form of air, land, water and waste pollution, both solid and wastewater. There are four parameters used in the technical aspect, including raw materials, processes, tools used, and human resource.

1) Cascara

Cascara is a tea made from dried red ripe coffee pulp and is usually also called coffee cherry tea. Coffee pulp waste has compositions such as carbohydrates (35%), 10% protein, fiber (30.8%) and minerals (10.7%), protein (8.9%), sugar (4.1%). Coffee pulp can be processed into special beverage products (delicious and healthy) with a very simple process but has very promising economic potential. [24] .

Not all of the coffee husk solid waste can be used as raw material for cascara tea because there is still a sorting step. Every 1,000 kg of Arabica coffee processing will produce 726 kg of solid waste. The amount of coffee skin waste used as raw material for cascara tea is 400 kg. The coffee pulps are dried until they reach a maximum water content of 8.00%. Cascara tea is made using cherry arabica coffee pulp waste as raw material which is dried in the sun for 2-3 days to a water content of 5.83%. The coffee pulp is then ground using a disk mill machine or can be ground finely. The fine coffee pulps are then packaged in tea bags and can be prepared to be cooked and then brewed like tea in general. Making cascara tea is only carried out by a small number of small coffee processing industries where the production process is carried out manually due to limited equipment. The minimum equipment required is an oven, disk mill and hand sealer

2) Animal feed

The use of coffee pulp is considered very important because the volume is very high. The pulp can be used as animal feed. The peeled coffee pulp waste is then mixed with bran according to the treatment and sprayed with EM4 solution. Then stir until mixed into a dough which is then put into plastic [25]. The activity of making animal feed is carried out manually, the tools needed include: tarpaulin, plastic, shovel, stirrer, sack, scales and hand sprayer.

3) Biogas

The biogas production pattern in the anaerobic coffee processing wastewater process uses livestock manure and coffee wastewater in a ratio of 1:1. The process of making biogas is carried out anaerobically (without the presence of oxygen) to produce gas in the form of methane gas (which has flammable properties) and carbon dioxide. The anaerobic decomposition process is assisted by a number of microorganisms, especially methanogenic bacteria, temperature and pH (degree of acidity) [26].

The best pH condition for producing biogas is 8.5. In agro-industry, the waste pH condition is only around 5 - 9, meaning that the activity of methanogenic bacteria or the growth of microorganisms in the formation of biogas is hampered due to the influence of acidic pH, so it is necessary to add NaOH so that the solution in the digester is in a neutral condition and can improve the quality and quantity of biogas. At a temperature of 30-55 ºC, microorganisms can work optimally breaking down organic materials [27]. A biogas reactor with a filling volume of 2,000 liters of a mixture of livestock manure and coffee processing wastewater is estimated to produce 7.9 m3 of methane gas every day. The tools needed in the process of making biogas are a biodigester, reactor, pH meter and others.

3.5 Financial feasibility analysis

Financial feasibility analysis is used to determine whether the implementation of clean production can continue or not by determining the costs required to implement cleaner production and calculating the benefits and savings from implementing cleaner production. Financial analysis looks at the net present value (NPV), internal rate of return (IRR), benefit cost ratio (B/C), and pay back period (PBP). The following is a financial analysis of each alternative action for implementing cleaner production.

1) Cascara

Utilizing coffee pulp waste into cascara tea will reduce the waste produced, especially solid waste and can increase the income of small coffee processing industries and surrounding communities. Based on the results of financial calculations for making cascara tea, it is satisfactory, namely the NPV value is IDR 1,368,544,232,-; IRR 52%; B/C Ratio 6.08; and PBP 0.90 or 10 months. The calculation assumes that the production of cascara tea is sold out at an interest rate of 10%.

2) Animal feed

Utilizing coffee pulp waste into animal feed will reduce the solid waste produced and be able to provide animal feed in the long term. Based on the results of financial calculations for making animal feed, it is satisfactory, namely the NPV value is IDR 1,341,572,225; IRR 52%; B/C Ratio 6.08; and PBP 0.90 years or 10 months.

3) Biogas

The biogas alternative is planned to only be used by small coffee processing industries because it is close to the waste water channel location. Based on the financial calculation results for making biogas, it is satisfactory, namely the NPV value is IDR 1,893,567,029,-; IRR 52%; B/C Ratio 6.08; and PBP 1.4 years.

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3.6 Analysis of determining priorities for implementing cleaner production

Decision making uses the Analytical Hierarchy Process (AHP) method to obtain values, there is a ranking step in determining alternative clean production actions. The selection of alternative priority scales for cleaner production actions is carried out by determining the weights with the help of the expert choice application as shown in Table 3. Identifying problems in each process and input and output flow for Arabica coffee processing. This action was carried out to identify the potential for implementing cleaner production which can be implemented, there are several alternatives, namely cascara tea, animal feed and biogas involving the main products in the form of coffee beans and ground coffee, both Arabica varieties. After carrying out a hierarchical analysis of criteria, actors, objectives and alternatives, an analysis is then carried out on the main objective, namely the potential for waste utilization.

Table 3: Results of ranking alternative cleaner production

Objective	Alternative		
	Cascara	Biogas	Animal feed
Improved environmental quality	5,377	1,858	0,996
Optimizing agro-industrial potential	5,547	1,878	0,998
The increase in community income	5,972	1,736	0,847
Total score	16,896	5,472	2,841

These alternatives will be compared to which one has the best results so that it can be applied to partners. Based on Table 3, it can be seen from the ranking results of the most feasible alternative clean production action with the highest weight value of 16.896, cascara tea. This shows that cascara tea is the most prospective alternative measure for implementing cleaner production.

Based on mass balance analysis, technical and financial feasibility analysis and priority determination analysis using the AHP method, there are 3 alternatives for implementing clean production that can be applied, including cascara tea, animal feed and biogas. The most priority alternative product to be implemented is cascara tea. The results of the financial feasibility analysis study of this alternative are NPV Rp. 1,368,544,232,-; IRR 52%; B/C Ratio 6.08; and PBP 0.90 or 10 months. Cascara tea is an alternative for utilizing coffee pulp waste so as to minimize the solid waste produced in downstream coffee products.

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4. CONCLUSIONS

The most effective use of coffee pulp waste for small coffee processing industries is cascara. The results of the mass balance analysis in 1,000 kg of Arabica coffee production produced coffee beans with horny skin or coffee with hard skin (HS) with a water content of 5.83% of 283 kg, solid waste 726 kg, coffee processing wastewater 1,613 kg. Cascara tea showed the highest financial feasibility where an NPV value of IDR 1,368,544,232 was obtained; IRR 52%; B/C Ratio 6.08; and PBP 0.90 or 10 months. The calculation assumes that the production of cascara tea is sold out at an interest rate of 10%. The use of solid waste for animal feed is not carried out because there are groups of breeders who use raw materials from partners as animal feed. Biogas is also not the focus of this activity because it requires a high investment value.

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