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SMALLHOLDER COFFEE PROCESSING DESIGN USING WET TECHNOLOGY BASED ON CLEAN PRODUCTION

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Abstract: Wet processing for red coffee berry is intended to improve smallholder coffee quality despite produce wastewater that can pollute the environment. In order to minimize and prevent wastewater generated from processing, then it should be designed coffee processing based on water minimization as part of clean production. The purpose of this study is to design smallholder coffee processing using wet method based on clean production that can provide added value and environmental friendly. This study use experimental approach through water minimization design and wastewater treatment alternatives. Alternative use of biodiesel also analyzed as a preliminary study. The results showed water minimization in wet processing could improve coffee quality. Minimum water volume for coffee pulping and washing are 0.73 – 0.78 and 2.25 – 2.56 $m^3.tonne^{-1}$ coffee berry, respectively. Highly concentration of coffee wastewater caused by water minimization strategy is a great potential to produce biogas as alternative fuel sources. Wastewater treatment alternatives which can be applied are neutralization, anaerobic, coagulation flocculation, filtration and sedimentation. There are also added-value byproducts generated from coffee processing such as biogas, irrigation water, compost, organic fertilizer, animal feed and briquettes. Biodiesel use in coffee processing increase the efficiency of energy consumption and reduce carbon emissions impact.

Keywords: Coffee, wastewater, wet processing, coffee quality, anaerobic process

INTRODUCTION

Coffee has been giving its own benefit for Indonesian people as the main income for more than one million small farming families (smallholder) and for upstream or downstream businesses. Most of the coffee types that cultivated in Indonesia are robusta. About 86.38% cultivated coffee in Indonesia are robusta where 96.33% are from smallholders [1]. The low quality of robusta coffee produced by smallholders is generally caused by post-harvest processing using dry processing which produced coffee beans called *Asalan* Coffee. This quality causes low price of coffee beans on farm level. There is a way to improve the quality of coffee in order to increasing price through proper post-harvest handling before selling to exporters. Proposed processing stages are wet processing for red-picking coffee fruit. Unlike dry processing with less waste, wet processing uses water to peel and wash. But, in wet processing, coffee fruit get fermentation that believed can enhance the flavor [2-4].

For minimizing and preventing waste from wet process, it needs to design the process with water minimization. Water minimization as a part of cleaner production concept is an effort to increase coffee bean quality while to decrease the environmental impact. This research aims to design the smallholders coffee process using wet-process technology based on clean production which gives added value and environmental friendly.

MATERIALS AND METHODS

Data used in this study were primary and secondary data from experimental results, observation and literature studies. The stages of this research are; (1) water minimization design on wet-technology modification for smallholder coffee processing using mass balance analysis, quality and technological feasibilities analysis, (2) alternative design for wastewater treatment from coffee processing using anaerobic (biological) process, coagulation flocculation (chemical) and filtration (physical).

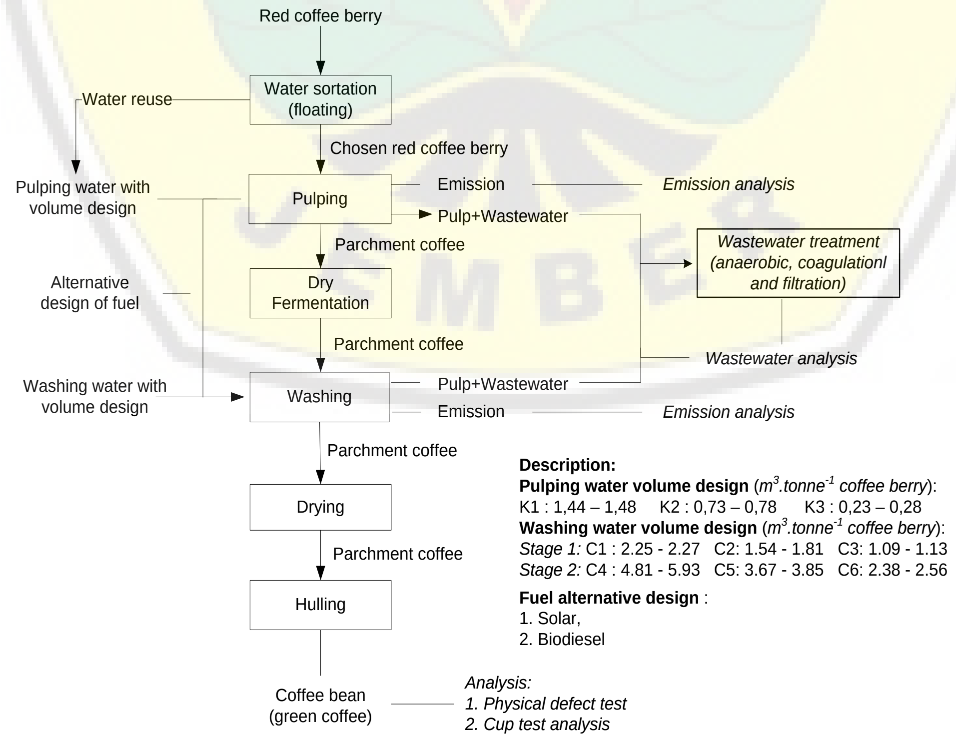


Fig. 1: Experimental design

RESULTS AND DISCUSSION

Water minimization of coffee processing

Water minimization conducted based on water volume per tonne of coffee berry that can be processed according to equipment capability. Pulping and washing of wet coffee processing have potentially produces waste water. Mechanic pulping still leave pulp and mucilage residues on thin layer skin surround the beans. Dry fermentation process for 12-24 hour and washing are combination method to remove the rest of mucilage layer. The water content of parchment coffee at final stage should be lowered to 12-12.5% according to SNI 01-2907-2008 (Indonesian Standard of Coffee Bean). Using mass balance known the potency of wastewater decreases and resulted for 18-19% yield of coffee bean (Fig. 2). Water minimization treatment from pulping stage has significant effect for waste water volume, solid waste and number of beans. Minimum water volume can inhibit separation between pulp and beans then cause uncompleted peeling. Water minimization on washing process affect wastewater volume significantly (Table 1).

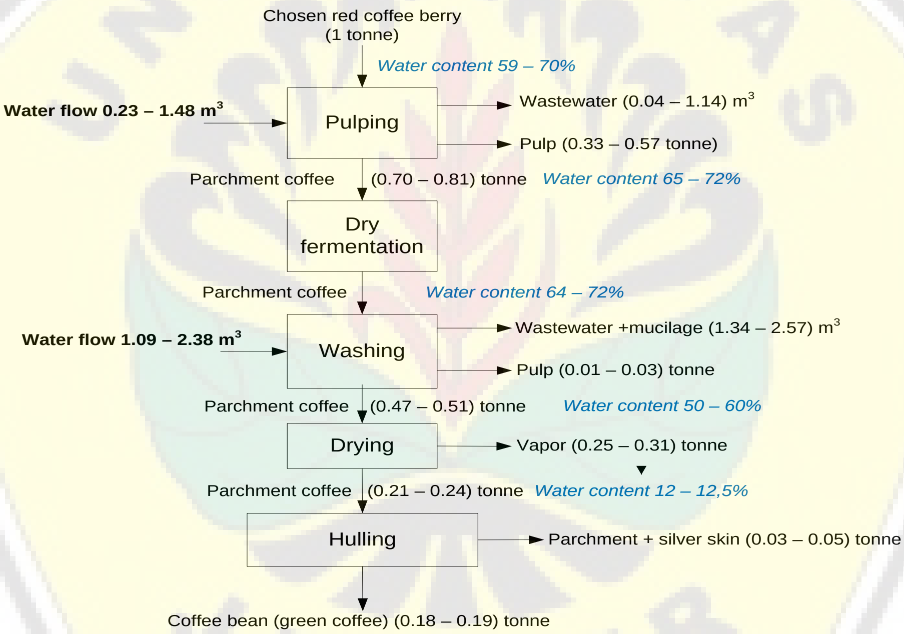


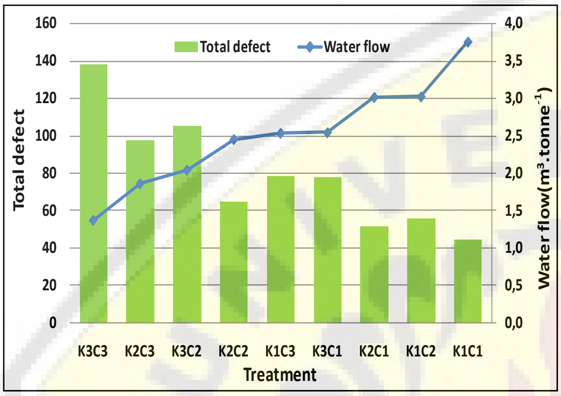
Fig. 2: Mass balance of coffee wet processing

Table 1. Results of Duncan continue test from pulping and washing process

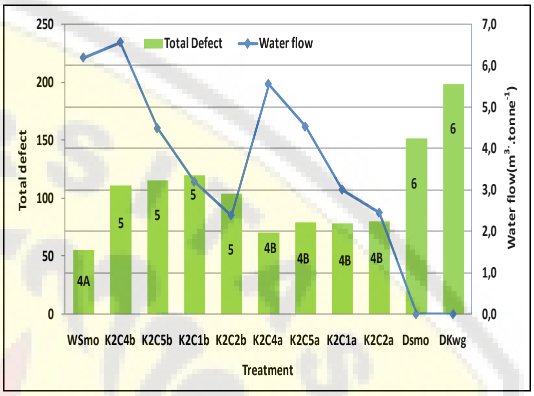
Treatment	Pulping (kg)			Washing (kg)		
	Wastewater	Pulp	Parchment coffee	Wastewater	Pulp	Parchment coffee
K1C1	57.00[b]	28[ab]	39[ab]	134.05[b]	0.6[a]	23.50[a]
K2C1	20.70[a]	28.25[ab]	38.75[ab]	132.78[b]	1.23[a]	24.25[a]
K3C1	10.835[a]	16.5[a]	37.00[a]	133.125[b]	0.925[a]	24.00[a]
K1C2	56.15[b]	27.00[ab]	40.75[ab]	107.70[a]	1.05[a]	25.50[a]
K2C2	20.35[a]	27.00[ab]	39.75[ab]	104.125[a]	0.875[a]	25.50[a]
K3C2	6.59[a]	20.25[a]	35.00[a]	114.975[ab]	1.225[a]	23.50[a]
K1C3	53.8[b]	27.75[ab]	40.5[ab]	80.5[a]	1[a]	26.25[a]
K2C3	20.055[a]	26.5[ab]	40.0[ab]	91.725[a]	0.975[a]	25.50[a]
K3C3	2.05[a]	23.75[a]	37.50[a]	87.775[a]	0.775[a]	25.50[a]

Coffee quality improvement through wet processing based on water minimization

The quality of coffee characteristic determined by consumer [5]; [6]. Quality analysis of coffee bean include: (1) physical quality of beans from pulping and washing (2) physical and cup quality of beans from washing with water minimization. Based on the result of Duncan test and physical quality of coffee beans from pulping and washing process, the limit of water minimization in pulping process is about 0.73-0.78 $m^3.tonne^{-1}$ coffee berry (K2). These result becomes a standard to know the physical and cup quality from washing process with wáter minimization.



Pulping and washing treatment



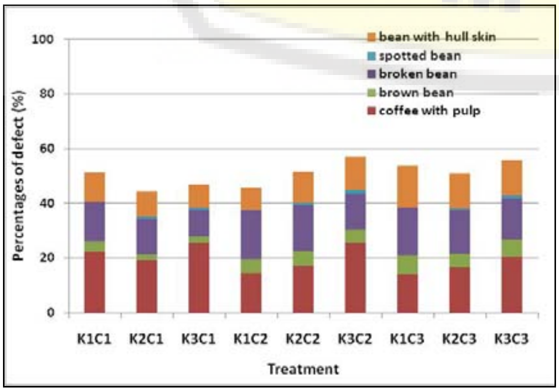
Washing treatment

Fig. 3: Physical quality of coffee bean with water minimization treatment

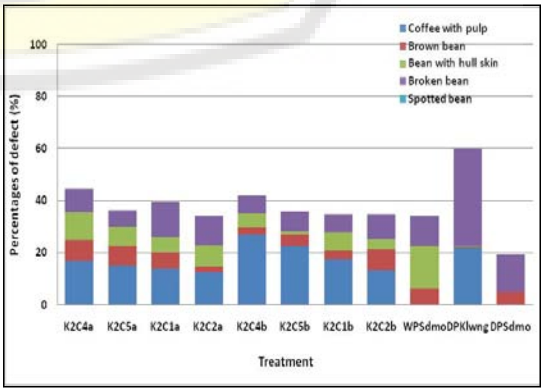
Notes : a = coffee from peak harvest, b = coffee last harvest, WSmo : wet coffee bean from Sidomulyo village, DSmo = dry coffee bean from Sidomulyo village, DKwg = dry coffee bean from Kaliwining plantation

Coffee defects divided based on (1) defects from farm, (2) defects because of processing and (3) other materials non coffee bean [7]. Based on the results, water minimization on pulping process affect defect of processing and water minimization on washing process mainly affect physical defect because other material non coffee beans.

Coffee with pulp is the defect that happened in pulping process and not preferred by consumer because of dominant taste of pulp. Large number of coffee with pulp defects found in coffee bean that using at least of water at pulping. Other dominant defects come from broken beans which giving burn taste after roasted. Broken beans can happen because huller machine works imperfectly or because beans have unequal size after drying. Imperfect washing could increase high water content in coffee bean, further affect the huller mechanism after drying [3].



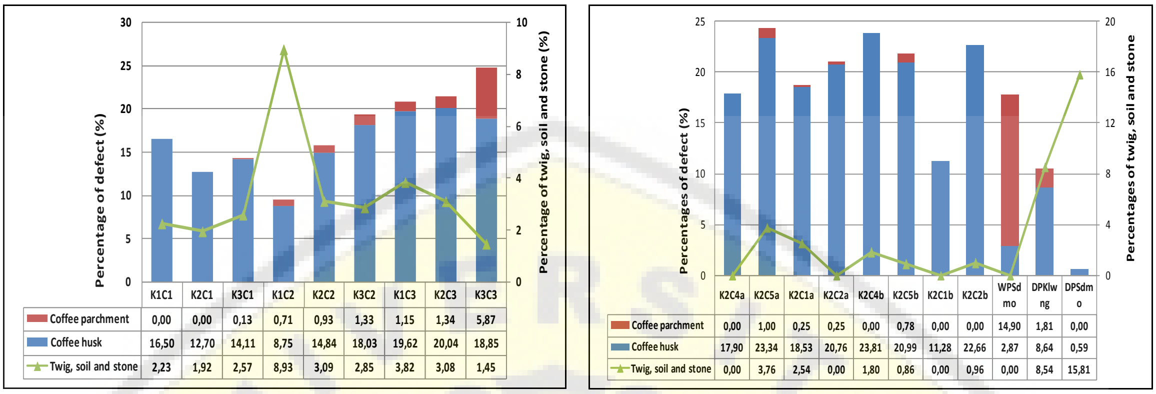
Pulping and washing treatment



Washing treatment

Fig. 4: Coffee defect percentages of processing treatment

Other material non coffee defect is dominant defects that occur due to lack of water in pulping and washing process. If total defect because other material non coffee reach 20-25%, coffee is classified as *Asalan* Coffee [8]. Otherwise, other material non coffee defect can be minimized by doing grading after hulling.



Washing and pulping treatment *Washing treatment*

Fig. 5: Other material non coffee defect percentages

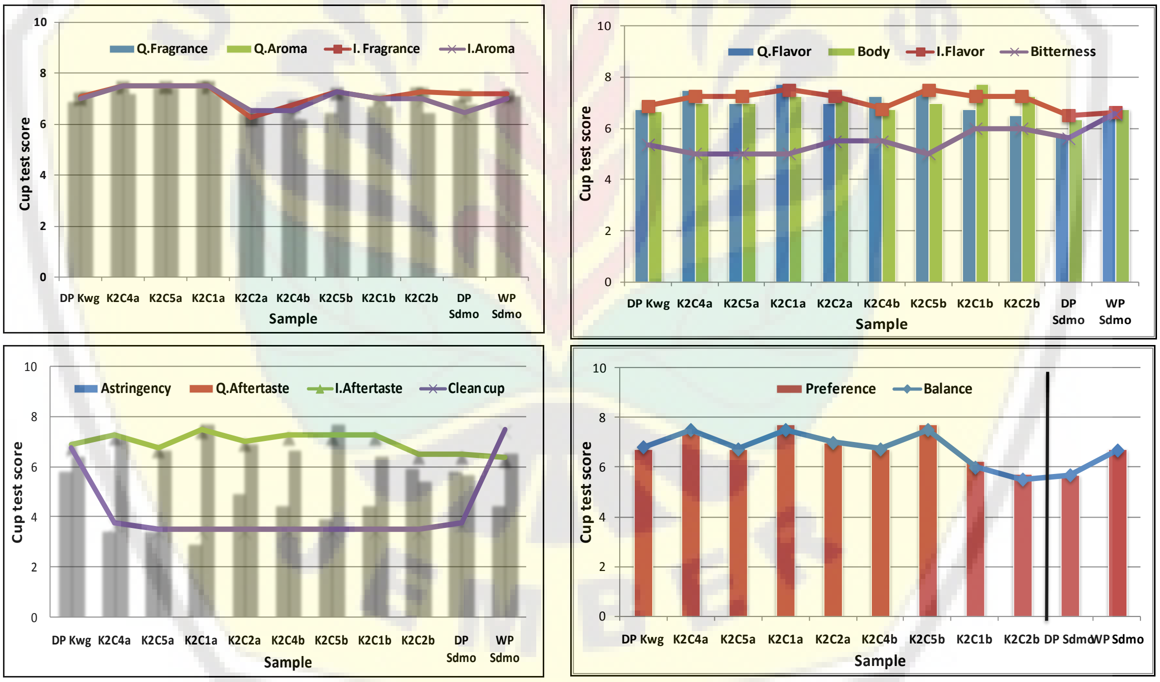
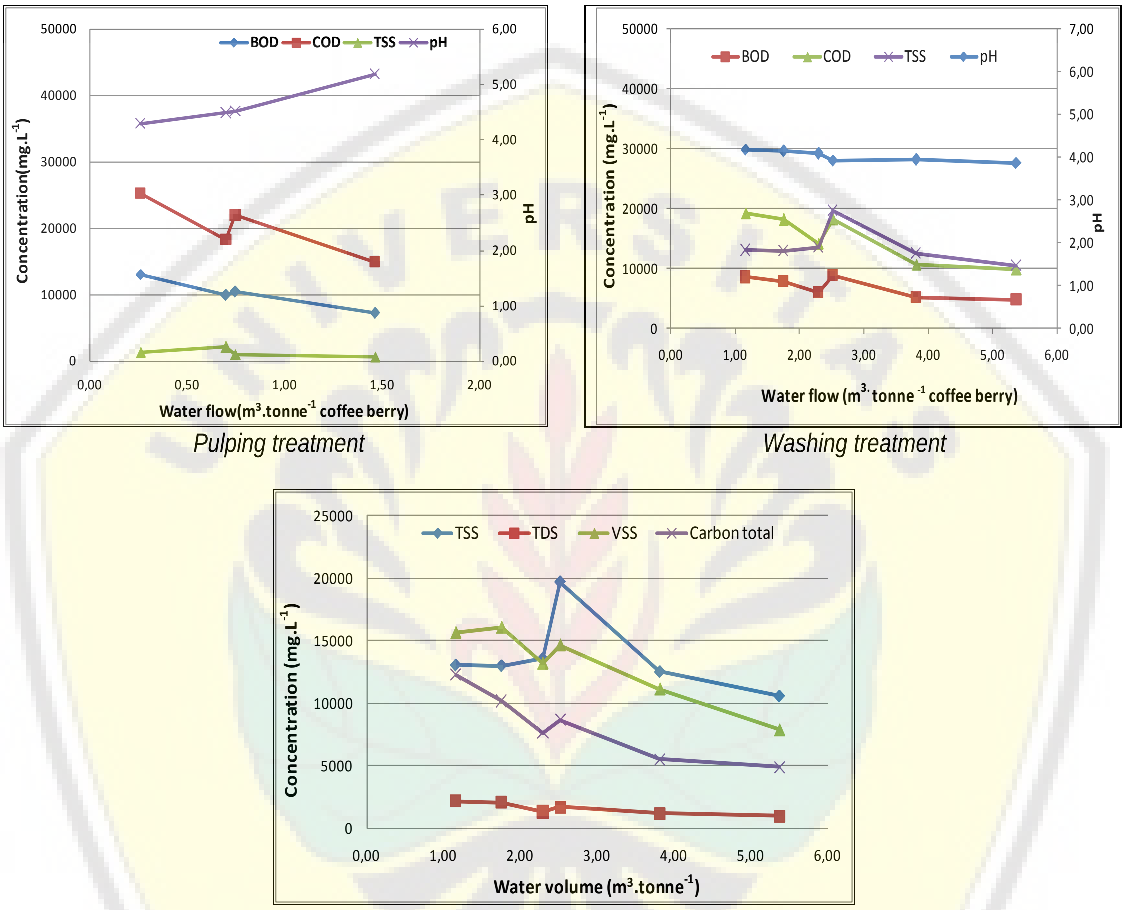


Fig. 6: Cup test of washing treatment coffee

Generally, wet process can improve coffee cup. Water minimization can increase quality and fragrance intensity also flavor from roasted coffee. It is also common for flavor and body although the difference is not really obvious. Bitterness, a caffeine indicator which is a specific characteristic from robusta coffee, tends to decrease because of wet process. Generally, the smaller caffeine contents the tastier coffee taste [9]. Clean cup refers to coffee flavor without defect and free from coffee bean defects. Minimization water will affect clean cup attribute. Assessment of balance and preference attribute indicates preference of panelist for coffee from wet processing with a tendency to choose minimum water in coffee washing (C6).

Wastewater Treatment Analysis of coffee processing with water minimization

Water minimization made to reduce wastewater volume without affect the coffee quality. Minimum volume of water input that can be used for pulping and washing are 0.73 – 0.78 and 2.25 – 2.56 $m^3.tonne^{-1}$ coffee berry. Wastewater volume decreases until 50% and even to 80% rather than those general wet processing. Water minimization can decrease the volume but it may affect the wastewater quality that produced [10].



Pulping treatment

Washing treatment

Washing treatment

Fig. 7: Water minimization impacts for wastewater quality

Wastewater from minimization treatment has higher concentration of organic pollution while water volume is lower. Organic material in wastewater mainly comes from pulping process of fruit and mucilage. Low pH values (4.0) derived from fermentation process of sugar component from pulp and mucilage into acetic acid [11]. Acidity and high organic content in wastewater require specific handling in order to environmental safety.

Direct fuel using and coffee processing emission analysis

Direct fuel using analysis in this study was conducted to determine the effect of different fuel consumption for energy needs for processing and emissions that released into environment. Fuel selection can save energy consumption and environmental friendly. Low emission levels of biodiesel can reduce the impact of air pollution and greenhouse effect till 40%. Therefore, it is necessary to make further study on utilization of alternative fuels used in coffee processing.

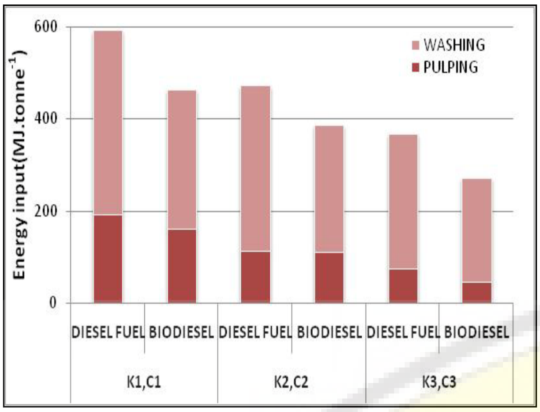


Fig. 8: Energy input in coffee processing

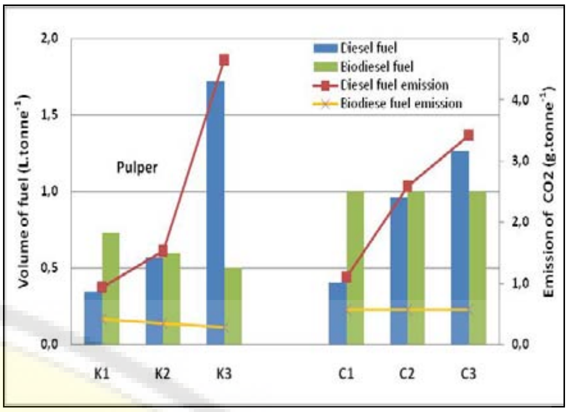


Fig. 9: Volume of fuel and emission

Wastewater treatment using anaerobic process

Water minimization treatment that is chosen is in the range water volume process 2.99 m^3 – 3.34 $m^3.tonne^{-1}$ coffee berry. On this treatment, coffee bean quality has improved than that from dry processing and showed no difference with higher water volume of minimization treatment. Waste water characteristic indicates the suitability of waste water treatment using anaerobic process in digester to produce biogas as by-product.

Table 2: Mass balance of chosen water minimization in wet coffee processing

Components	Input	Output	
		Coffee bean	Waste
Coffee berry, kg	1000		
Water processing, kg (average)	3012		
Total, kg	4012		
Coffee bean, kg		185	
Coffee skin, kg			565
Pulp, kg			24.6
Hull, kg			53
Wastewater + mucilage, kg			2937.4
Losses, kg			247
Total, kg		4012	

Wastewater from coffee processing neutralized with adding limestone ($CaCO_3$ = $1 g.L^{-1}$) until it reaches a neutral pH (6.5-7.5) before it flows into anaerobic digester. Anaerobic digester (30 m^3 capacity) has been operated before coffee harvest with input solution from cow manure (1:1). Biogas formation occurred after 21 days and produce 2-6 $m^3.d^{-1}$ (Fig.10.). Total production of biogas reached 16 – 18 $m^3.d^{-1}$ until coffee harvest. When coffee harvest, livestock manure input solution was replaced by wastewater from coffee processing. Methane gas composition in biogas reaches 60%. The rate of biogas production increases after 20 days while input from wastewater coffee processing are unto 40 $m^3.d^{-1}$. Biogas production rate from coffee wastewater is higher than using manure solution (Fig.11).

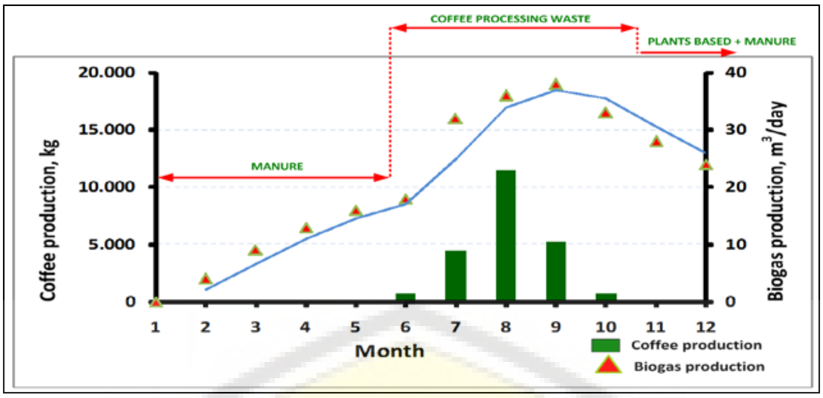


Fig. 10: Biogas rate production during coffee production cycle

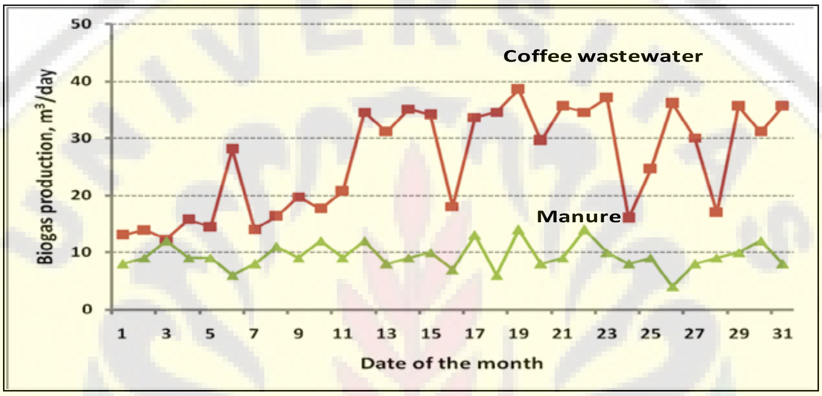


Fig. 11: Biogas daily production based on two kinds of input

Through hydrolysis, acidogenesis and methagenesis in anaerobic treatment, coffee wastewater concentration can be reduced untill 90% and produce biogas contained methan, carbondioxyde, hydrogen, nitrogen, and other volatile acids. Methane has fuel potencial that can be used as energy resources [12]. Biogas is one of alternative utilization from anaerobic by-product which contribute to energy or fuel need. Biogas can be used in cooking, lighting, water pumping, boiler and etc.

Table 3: Water and anaerobic wastewater characteristic

Water	pH	BOD ($mg.L^{-1}$)	COD ($mg.L^{-1}$)	BOD/COD	TSS ($mg.L^{-1}$)
Input water processing	7.15	35	80		32
Wastewater	4.20	8,314	18,774	0.44	10,943
Anaerobic effluent	6.57	820	2160	0.38	920
Percentage of reduction (%)		90.13	88.50		91.60

Chemical and physical process of coffee wastewater

The alternatives of wastewater treatment from coffee processing are chemical and physical processes. Chemical process through coagulation flocculation is the chosen process because its effectiveness, cheapness and easiness to handle waste water along with optimum process condition [13]. Physical process with filtering process is old treatment that has been used for wastewater of coffee production in Indonesian big plantation.

Table 4: Efficiency of chemical and physical process treatment

Treatment	Early pH	COD input (mg.L^{-1})	Optimum pH : dosis(g.L^{-1})	COD output (mg.L^{-1})	COD efficiency (%)	Colour efficiency (%)
Chemical coagulant						
a. Alum	4.5	5,000	6.0 ; 5.0	2,453	50.93	89.15
b. FeCl3	4.5	5,000	6.0 ; 7.5	1,404	71.91	97.84
c. Alum + Ca	4.5	5,000	6.0 ; 5.0	2,121	57.58	88.47
d. FeCl3 + Ca	4.5	5,000	6.0 ; 7.5	1,449	71.02	96.36
e. Alum	7.12	988.80 a)	6.0 ; 5.0	191.01	80.68	70.48
f. PAC	7.12	988.80 a)	7.0 ; 5.0	137.49	86.10	88.25
Filtering through palm fiber-	4.64	987.16 b)		618.08	37.39	45.08
ijuk, active carbon & zeolit)	7.12	988.80 a)		622.33	37.06	40.15

a) Anaerobic effluent from Indonesia Coffee and Cacao Research Institute
b) Wastewater from rural coffee proceesing at Sidomulyo village, Jember Regency

Smallholder coffee processing design based on clean production.

Water minimization of wet processing for smallholder coffee processing can improve coffee bean quality although the yield of waste water and solid water can pollute the environment. Utilization of solid waste into compost, organic fertilizer, animal feed and briquettes have been done and proven to reduce environmental pollution and provide added value to the farmer [14];[15]. Based on the alternative wastewater and solid waste treatment, it can be made a small coffee processing design with giving added value and environmentally friendly.

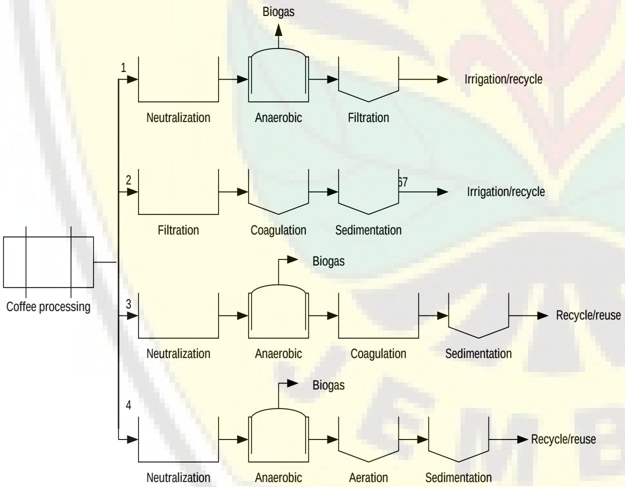


Fig. 12: Wastewater treatment alternatives

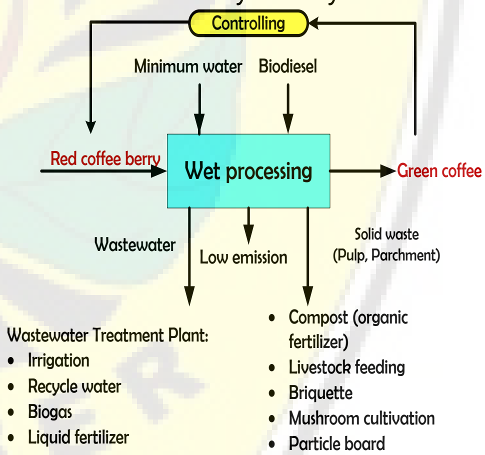


Fig. 13: Smallholder coffee design

CONCLUSIONS

Water minimization in small coffee processing which are used wet processing can be used to improve coffee bean quality. Minimum water volume for pulping and washing process are 0.73 – 0.78 and 2.25 – 2,56 m^3.tonne^{-1} coffee berry. High concentration of waste water is a potensial to produce biogas as one of alternative fuels. Alternative waste water treatment that may applied are neutralization, anaerobic, coagulation flocculation, filtration and sedimentation. Various byproduct with added value from small coffee processing are biogas, water irrigation, compost, fertilizer, animal feed and briquettes. Using alternative fuel (biodiesel) for coffee processing can reduce emissions and environmentally friendly.

Alternative waste water treatment from coffee process and biofuel utilization as an effort to improve the energy efficiency and to reduce the greenhouse effect is determined by appropriate level on farmer level. It needs to do financial feasibility study as a base for implementation small coffee process with water minimization. This implementation will be affected by various factor such as technology, environment, social cultural, institutional and government policies. Therefore, it needs in-depth study that related to various factors to support small coffee processing with quality and environmentally friendly oriented.

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