Eco-Efficiency Analysis of Waste Cooking Oil Recycling Into Liquid Dish Soap Using Life Cycle Assessment

by Sri Hartini

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Eco-efficiency analysis of waste cooking oil recycling into liquid dish soap using life cycle assessment

Sri Hartini[1*]**,** Yusuf Widharto[1], Salsabilla Rachmajihan Indarto[1], Galu Murdikaningrum[2]

[1]Department of Industrial Engineering, Diponegoro University, Indonesia
[2]Departement of Chemical Engineering, Insan Cendekia Mandiri University, Indonesia

Corresponding author: srihartini@lecturer.undip.ac.id

Abstract. Waste Cooking Oil (WCO) is an oil with a chemical composition that contains carcinogenic compounds formed during the frying process and unsaturated fatty acids. Improper handling of WCO can cause environmental pollution, especially water and soil. However, several studies have provided information that WCO has the potential to be recycled into products that are more value-added and have economic potential. Previous research has succeeded in finding the best combination of treatments for making soap from waste cooking oil that meets the standards of SNI 06-2048-1990, namely with a concentration of 22.5% KOH, cooling method and adsorption of activated charcoal and kepok banana peels. This study intends to analyze the environmental impact if WCO is recycled into liquid dish soap. The analysis was carried out using Life Cycle Assessment with the help of simapro software. The recycling process has the greatest impact on indicators of climate change and acidification. The eco-efficiency index is included in the affordable and sustainable categories.

1. Introduction

The management of used cooking oil that has not been optimal causes the amount of WCO that is discharged into the environment is still high and dangerous for the environment [1]. Therefore, the management of WCO has become a public concern in recent years [2]. Based on a survey in Semarang, 90% of households and 67.6% of culinary businesses dispose of noodles into sewers, soil, or garbage [3]. WCO waste is spread throughout the Semarang City [4]. WCO can damage the water and soil environment [5], damage aquatic communities [6] and endangers human health. The discarded WCO waste causes the economic potential to not be utilized [7]. From previous studies, WCO that is disposed of without going through a recycling process contains a compound that has an ecotoxicity effect (fresh water) of 0.43 PAF.m3.day. This value is equivalent to an eco-cost of 2.39E-6 euros [8].

WCO recycling can produce more valuable products. WCO contains unsaturated fatty acids such as oleic acid, linoleic acid and triglyceride acid which can be utilized into oil-based products, such as solid or liquid bath soap [9]. Bath soap is a compound of sodium or potassium with fatty acids from vegetable oils or animal fats in the form of solid, soft, liquid and foamy and is used as a cleanser [10]. WCO can be used as raw material for making liquid soap after being filtered to remove spices, neutralized with KOH and the bleaching process. Hartini et al [8] have conducted an experimental design for making liquid dish soap with 12 treatment combinations. The combination of treatments gave different effects on each parameter used. The pH parameter is influenced by the method of manufacture and the concentration of KOH, where the cold method and the concentration of KOH 22.5% produces a lower pH. The parameters of free alkali are influenced by the method of manufacture and the concentration of KOH where the cold method and a concentration of 22.5% produce lower free alkali levels. Free fatty acids are affected by the manufacturing method and purification materials, where the cold method and activated carbon purification materials produce lower free fatty acid values. However, there are still very few studies that measure the environmental impact when WCO is recycled into soap.

This study aims to measure the environmental impact of the recycling process of WCO into soap, specifically liquid dish soap with banana peel as an adsorbent using Life Cycle Assessment (LCA). This is based on a survey conducted in Semarang, that people tend to choose dish soap as a WCO recycled product [3], [8].

2. Methodology

2.1. Life cycle assessment

LCA is one of frameworks to estimate the environmental burden of a product/process in an environmental impact assessment study [11]. LCA is used to quantitatively analyze environmental impacts based on material/energy consumption and the waste generated. LCA includes four steps, namely definition of objectives and scope, life cycle inventory analysis, life cycle impact assessment and interpretation.

2.1.1. Goal and scope. The Goal and scope include determining system boundaries, functional units and analysis period. Functional units are references related to inputs and outputs [13]. The system boundary determines the unit of the process being analyzed. The analysis period has a significant effect on the LCA results because of the energy consumption during the operation phase. LCA results are strongly influenced by the accuracy of the data.

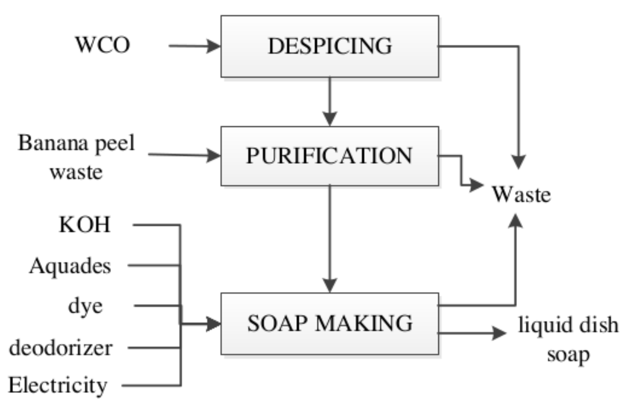

Figure 1. Scope of the research.

The goal of this research is to recycle WCO into liquid dish soap using kepok banana peel waste as an adsorbent and to measure the environmental impact of the process. The system studied includes the process of recycling WCO into liquid dish soap, including the process of despicing, purification, and soap making, Figure 1. The input is in the form of materials and energy used while the output is in the form of soap products and the resulting waste. Calculations were carried out with the help of SimaPro 9.1.17 software using Ecoinvent 3.

2.1.2 *Life cycle inventory (LCI)*. Basically, the LCI stage is the main data collection and compilation activity including input and output data. The data considered comes from the production system from the system that has been determined at the goal and scope stage. The results of the LCI will be input to the LCIA. Table 1 is a Life Cycle Inventory table that shows the input and output of the WCO recycling process into liquid dish soap with kepok banana peel as adsorbent.

Table 1. The input and output of of the WCO recycling process into liquid dish soap

Process	Input			Output		
	Material	Unit	Mass	Material	Unit	Mass
Despicing	WCO	g	112	*Reside*	*g*	*12*
Purification				*WCO*	*g*	*100*
	Banana peel	g	100	Banana peel waste	g	127
	WCO	g	100	WCO	g	73
Soap making	WCO	g	73	Liquid Dishwashing Soap	g	360
	KOH 22,5 %	g	22,5			
	Aquadest	g	77.5 + 200			
	Food coloring	g	2	Soap waste	g	17
	Fragrance	g	2			
	Electricity	kWh	0.1488	Emission		

2.1.3. Life cycle impact assessment (LCIA) . The LCIA phase aims to estimate the effect of the product/process produced by the LCI phase and convert it into various impact categories. The LCIA method can be single-category or multi-category [12].

2.1.4. Interpretation. The interpretation phase analyzes and evaluates the results of the LCIA and draws some conclusions from the system under study.

2.2. Eco-efficiency

Eco-efficiency is one of the clean production strategies, where clean production is a preventive and integrated environmental management strategy that is continuously applied to the production process and product life cycle to reduce risks to humans and the environment [14]. The principle of eco-efficiency is the principle of material and energy efficiency to reduce environmental impacts.

Calculation of the eco-efficiency index (EEI) to determine the feasibility of the product/system based on ecological efficiency and economic efficiency. EEI is obtained by dividing the net value by eco-cost [17]. The product/system is said to be unaffordable when its value is less than 1. If the value ranges from 0-1, it is included in the affordable category. The product/system is included in the sustainable category if the value is more than one [13],[15],[16]. Eco-costs are “virtual” costs, i.e. costs of prevention and damage in free trade. The following is the equation used to eco-efficiency analysis [13], [18], [19].

$$\text{Net Value} = \text{Selling price} - \text{Production Cost} \quad (2.1)$$

$$\text{EEI} = (\text{Net Value})/\text{Eco Cost} \ldots\ldots \quad (2.2)$$

The next parameter is the calculation of the eco-efficiency ratio (EER), which is the comparison between eco-costs and eco-indicators. The EVR calculation formula is described in equation 3.

$$\text{EVR} = (\text{Eco cost}) / (\text{Net value}) \ldots\ldots \quad (2.3)$$

Eco-efficiency ratio rate (EVR) is the final calculation of the eco-efficiency measurement. The EER calculation is obtained by subtracting the net value from the eco-cost value. The calculation of the EER rate is described in equation 4 [13].

$$\text{EER rate}=(1-\text{EVR}) \times 100\% \tag{2.4}$$

3. Result and discussion

3.1. Life cycle assessment

The characterization of the impact category of the recycling process from WCO into dish soap with the adsorbent of kepok banana peel waste produced by Sofyware Simapro is described in Table 2.

Table 2. The characterization of the WCO recycling process

Impact Category	Unit	Environment Impact
Climate Change	Kg CO_2 eq	3.19E-1
Acidification	Kg SO_2 eq	1.64E-3
Eutrophication	Kg PO_4-- eq	7.20E-4
Photochemical Oxidant Formation	Kg C_2h_4 eq	2.31E-5
Fine Dust	Kg PM2.5 eq	9.07E-5
Human Toxicity	Cases	2.93E-9
Ecotoxicity (freshwater)	PAF.M_3.day	9.89E+1
Metals Scarcity	Euro	3.52E-3
Oil & Gas Depletion excl energy	Kg Oil equ	4.87E-3
Water Stress Indicator	WSI factor	5.01E-3

The normalization stage is a stage that aims to assess activities that contribute to environmental impacts. The results of normalization of impact categories from the WCO recycling process into liquid dish soap using kepok banana peel as an adsorbent produced from the output of Simapro Software are described in Table 3. The weighting stage has the same value as the normalization stage because the weighting factor is 1.

Table 3. The normalization of the WCO recycling process

Impact Category	Normalization Factor
Climate Change	0.0370
Acidification	0.0144
Eutrophication	0.0030
Photochemical Oxidant Formation	0.0002
Fine Dust	0.0027
Human Tocicity	0.0027
Ecotoxicity (freshwater)	0.0006
Metals Scarcity	0.0035
Oil & Gas Depletion excl energy	0.0039
Water Stress Indicator	0.0050

The single score stage is a stage that aims to classify the value of the impact category of each process or activity. Based on the value of the single score, it can be seen the processes or activities that most contribute to environmental impacts and damage. Table 4 is a single score for the impact category of the WCO recycling process into liquid dish soap using kepok banana peel adsorbent.

Table 4. *Single score* of the WCO recycling process into liquid dish soap

Impact Category	Single Score (Euro)	Single Score (IDR)
Climate Change	0.0370	640
Acidification	0.0144	249
Eutrophication	0.0030	52
Photochemical Oxidant	0.0002	4
Fine Dust	0.0027	47
Human Tocicity	0.0027	47
Ecotoxicity (freshwater)	0.0005	9
Metals Scarcity	0.0035	61
Oil & Gas Depletion excl	0.0039	67
Water Stress Indicator	0.0050	87
Total	0.0730	1,264

The process of recycling WCO into liquid dish soap has an eco-cost value of IDR 1,264 for 1 time process of 100 g of WCO into 360 g of liquid dish soap. This process has the greatest impact on the environment in the indicators of climate change and acidification. The use of electrical energy derived from fossil fuels has an effect on the impact it causes.

3.2. Eco-effeciency index (EEI)

To analyze eco-efficiency, it begins with determining the net value which is determined by the product price and production costs. In this study, product prices and production costs are calculated for one product. The price of the product is based on the price of soap made from WCO with different adsorbents in the market place. The product price is 7500 IDR/unit. Production costs can be seen in Table 5. The recycling process can still get a profit of IDR 1,651. The calculation of production costs is carried out on a small scale with the assumption that it is carried out by the empowerment and family welfare group, so that labor costs are assumed not to be incurred. The marketing strategy carried out is also still utilizing the market place, which does not require marketing costs. Referring to these assumptions, the WCO recycling process produces an eco-efficiency index of 1.31, which is included in the affordable and sustainable category. This means that it is feasible in economic and environmental aspects. The results of eco efficiency are described in Table 6.

EEI increase can be done by increasing the net value or reducing production costs. The WCO recycling process using kepok banana peels produces an unattractive color and odor. Thus, this research adds dyes and fragrances in order to produce dish soap that is more acceptable to consumers. The addition of materials causes additional production costs and environmental impact costs. To increase EEI, it is necessary to study the recycling of WCO by using adsorbents that produce dishwashing products with attractive colors and odors, such as coffee grounds.

When the recycling process is carried out on an industrial scale, professional workers are needed who must be paid. In addition, the right marketing strategy is needed so that the product can be well received by consumers. The recycling process carried out on an industry scale will require equipment with a large capacity. This will affect the depreciation cost and the volume of product produced. Further research on the eco-efficiency of recycling WCO into liquid dish soap in industry scale is interesting to do in the next research.

Table 5. Production cost of liquid dishwashing soap

Item	Unit of Measure	Unit Cost (IDR)	Amount (unit)	Total Cost (IDR)
A. Raw Material Cost				
Oil filter paper	Pcs	995	2	1,990
Fragrance	mL	500	2	1,000
Food coloring	mL	133	2	267
Potassium hydroxide	Kg	23,000	0.02	506
Banana peel	Kg	1,000	0.1	100
Plastic packaging	Pcs	1,000	1	1,000
Waste cooking oil	Liter	4,000	0.1	400
Aquades	Kg	900	0.35	315
Subtotal				5,578
B. Equipment Cost				
Hand blender	Hour	18.06	1	18.06
Scale	Hour	13.82	1	13.82
Plastic container	Hour	0.47	1	0.47
SS spoon	Hour	0.11	1	0.11
Syringe	Hour	1.50	2	3.00
Gloves	Hour	1.20	2	2.40
Subtotal				38
C. Labor Cost	Hour	0		0
D. Electricity	kWh	1,352	0.17	234
E. Marketing Cost				0
Total Cost (A+B+C+D+E)				5,849

Table 6. The result of eco efficiency

Price (IDR)	Production cost (IDR)	Net value	Eco cost	EEI	EVR	EER
7,500	5,849	1,651	1,264	1.31	0.77	23%

4. Conclusion

The process of recycling WCO into liquid dish soap has the biggest impact on indicators of climate change and acidification. The eco-efficiency index has a value of 1.31 which means it is affordable and sustainable. This recycling process provides benefits that are greater than the costs of the environmental impact it causes. Future research is needed regarding the eco-efficient process of recycling WCO into liquid dish soap on an industrial scale. A study on the recycling of WCO using adsorbents from organic waste that has an attractive aroma and color is important to increase eco-efficiency.

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