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Life Cycle Assessment of Organic Arabica Coffee Products

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ABSTRACT

Upstream to downstream activities of organic Arabica coffee in Klungkung Village can cause environmental pollution and have the potential to be a contributor to increased greenhouse gases (GHG) and inefficient use of energy. On the upstream side, Arabica coffee cultivation activities use organic fertilizers, but the type and dosage of organic fertilizers are without proper knowledge. On the downstream side, it uses various technologies and produces various wastes that are not yet environmentally friendly. This study aims to determine how much the impact of processing organic Arabica coffee products on the environment can be reduced so that the product can be said to be feasible as an environmentally friendly product. The method used is Life Cycle Assessment (LCA) which has stages, goals and scope, life cycle inventory, life cycle impact assessment, and interpretation. Processing organic Arabica coffee products produces a GWP of 18.0589 kg CO2-eq, and the energy use efficiency shows a NER value of 0.03 and a NEV of -33.12. The recommended alternative improvements are making all solid waste into organic fertilizer and anaerobic handling of liquid waste to produce biogas which can be used as an alternative fuel to replace LPG in the roasting process. If the alternative recommendations for improvement are implemented, it can reduce the GWP value to 6.3514 kg CO2-eq and increase the efficiency of energy use consisting of NER values of 4.53 and NEV of 126.46.

1. INTRODUCTION

Indonesia is called as an agricultural country because agriculture plays important roles in the overall national economy (Imani *et al.*, 2018). Based on data from the Central Statistics Agency (BPS) for 2018, it shows that plantation crops and food crops are able to make the largest contribution to improving the economy in agriculture, reaching more than 50% (Fithriyyah *et al.,* 2020). Coffee is one of the leading plantation commodities that has a significant contribution to the Indonesian economy (Prayuginingsih *et al*., 2012). The existing agricultural system in Indonesia is still conventional to this day. This has negative impacts, such as degradation and decrease in soil fertility, causing erosion, reducing soil moisture, to major problems affecting the health of consumers of crop products due to the use of pesticides (Imani *et al*., 2018). Conventional farming systems also result in a decrease in land productivity as a result of the excessive use of chemical fertilizers and pesticides, thereby destroying the balance of soil nutrients and biodiversity. In addition, it can also cause environmental and social problems in the form of air and water pollution, chemical residues contained in agricultural products are also a problem for human health, as well as a decrease in the independence of farmers due to dependence on external chemical agricultural inputs such as the fertilizer and pesticide industry (Herawati *et al*., 2014).

Jember Regency is one of the areas in East Java that has the potential to produce coffee. Based on data from the Central Statistics Agency (BPS) for 2018, it shows that in 2017, Jember Regency was able to produce 11,863 tons of coffee (Izzah *et al*., 2020). In total there are 16,882 ha of coffee plantations in Jember Regency where 5,601.31 ha of which are smallholder coffee plantations with a business scale of 1-2 hectares (Prayugininingsih *et al*., 2012). Klungkung Village is the first largest contributor to smallhaolder coffee in Sukorambi District, Jember Regency. The types of coffee grown in the village include Arabica and Robusta coffee. Klungkung Village coffee yields vary, namely 0.7 to 1 ton per hectare for Arabica coffee and 1 to 2.5 tons per hectare for Robusta coffee (Izzah *et al*., 2020). Cultivation is applied only by using organic fertilizers derived from goat manure and compost (made from leaf waste, twigs, wood powder and bran). The type and dosage of using organic fertilizers is only based on habits without knowledge about the correct use of fertilizers. In addition, wet processing is carried out on the downstream side of organic Arabica coffee, while organic Robusta coffee is dry processed into coffee products by the people's coffee agro-industry in Klungkung Village which is a development of the activities of farmer groups there (Izzah *et al*., 2020).

Based on these activities, local farmers and agro-industry players often think that they have implemented an organic farming system from upstream to downstream for coffee products. Organic farming is an agricultural cultivation system that relies on the use of natural ingredients without the use of synthetic chemicals (Mayrowani, 2012). This is reinforced by the statement that the philosophy of organic farming is to return all organic elements to the soil in the form of plant residues, manure and compost in doses that are suitable for plants and are useful in increasing plant and soil fertility (Hamka & Bubun, 2018). The goals of organic farming include making higher quality products in adequate quantity, cultivating plants naturally, encouraging and increasing the biological life cycle in agricultural ecosystems, increasing soil fertility in the long term, reducing and avoiding all forms of contamination due to the application of agricultural techniques, genetic diversity is maintained and increased, and social and ecological impacts can be considered (Imani *et al*., 2018).

The development of organic farming in Indonesia has increased every year (Hoesain *et al*., 2020). Based on the results of the 2014 Indonesian Organic Agriculture Statistics report, it shows that the area of organic land in 2008 - 2010 reached 103,908.9 ha, but decreased in 2011 - 2014 to 67,426.57 ha (Imani *et al*., 2018). The decrease in organic land area is caused by several factors, including farmers who want high production yields, slow plant growth, and the economic value obtained is not comparable to production results (Hoesain *et al*., 2020). The application of organic farming systems experiences many obstacles. This results in a small number of farmers actually implementing it due to a lack of support from socio-economic factors (Artini, 2017).

Even though the Arabica coffee farming system in Klungkung Village is carried out organically, it is necessary to develop a method that can evaluate the production process or the life cycle of coffee products so as to minimize negative impacts on the environment as an effort to develop sustainable products. In accordance with the revision of the Minister of Environment Regulation Number 1 of 2021 concerning PROPER (Company Performance Rating Program in Environmental Management) a new criterion has been added, namely compliance with the application of Life Cycle Assessment (LCA). LCA is a method of analyzing the entire cycle starting from the production process to waste treatment which is used to determine the amount of energy, costs and environmental impacts caused by the stages of the product life cycle starting from taking raw materials until the product is finished being used by consumers (ISO 14040, 2006). To implement this LCA, the Ministry of Environment and Forestry has determined in September 2021 the Guidelines for Compiling a LCA Report.

The life cycle assessment (LCA) of organic Arabica coffee products in the Klungkung coffee agro-industry aims to determine how much the impact of organic Arabica coffee products on the environment can be reduced, so that these products can be considered as environmentally friendly products. The objectives of this research include determining the mass balance and energy balance of organic Arabica coffee products based on the Life Cycle Inventory (LCI), determining the environmental impact generated in each process of the life cycle of organic Arabica coffee products based on the Life Cycle Impact Assessment (LCIA), and providing alternative recommendations for improving the production process to reduce environmental impacts on the Klungkung coffee agro-industry based on Interpretation at the Life Cycle Assessment (LCA) stage.

2. MATERIALS AND METHODS

This research was conducted from June to December 2021 in Klungkung Village, Sukorambi District, Jember Regency as the location for an organic Arabica coffee garden (upstream) and Banjarsengon Coffee House, Jalan Sriti No. 138, Banjarsengon Village, Patrang District, Jember Regency as the location for the Klungkung organic Arabica coffee processing agro-industry (downstream). Klungkung Village is the first largest contributor to smallholder coffee in Sukorambi District, Jember Regency. The types of coffee grown in the village include Arabica and Robusta coffee. Klungkung Village coffee yields vary, namely 0.7 to 1.0 ton/ha for Arabica coffee and 1.0 to 2.5 ton/ha for Robusta coffee (Izzah *et al.*, 2020). Map of the location of this research can be seen in Figure 1.

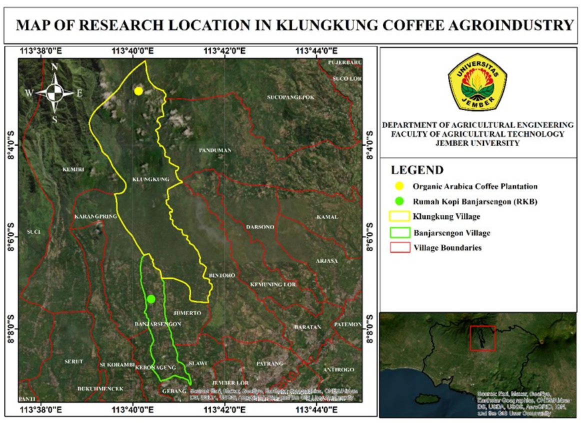


Figure 1. Map of research locations

2.1. Tools and materials

The equipment used in this study can be seen in Table 1, while the materials used can be seen in Table 2.

Table 1. Research equipment

No.	Tools	Use
1.	Tools and machines for the cultivation and production of	To carry out an inventory and calculate the energy balance as part of the Life Cycle
2.	Scales	To measure the mass of materials to be used in making a mass balance as part of the Life Cycle
3.	Camera	For research documentation
4.	Calkulator	To calculate mass, environmental impact in the form of emissions, direct energy, and energy efficiency using the equations used

Table 2. Research materials

No.	Material	Use
1.	Organic Arabica coffee of Rambusa brand 150 grams	For the main research material in making mass balances and energy balances
2.	Water	For materials in the manufacture of mass balance and energy balance
3.	Disturbed and undisturbed soil samples	To determine the parameters of soil type, texture, and organic C
4.	Waste of organic Arabica coffee production	For materials in making mass balances, determining impacts, and alternative
5.	Organic Arabica ground coffee products	For materials in the manufacture of mass balance and energy balance

2.2. Method

2.2.1. Goal and Scope Determination

Determining goals and scope is the first step in the LCA method which must be established as a clear reference and limitation in its implementation, so that it can answer the problems to be resolved. The problem referred to in this study is the magnitude of the environmental impact caused on the life cycle of organic Arabica coffee products, so that recommendations for improvement can be given to reduce the magnitude of the impact. This research has a main goal or objective, namely to find out how much the impact of organic Arabica coffee products on the environment can be reduced, so that the product can be said to be feasible as an environmentally friendly product. While the scope or scope of this research is cradle to gate (process in the factory) covering the cultivation of organic Arabica coffee to the handling of organic Arabica ground coffee waste production. Details of the scope of this research are presented in Figure 2. It is known that the scope of this research starts from the cultivation stage to the sealing process of organic Arabica ground coffee products. The sub-stages of production whose environmental impact is taken into account are only the stages that produce greenhouse gas emissions from the use of organic fertilizers, water, fuel, and electricity in agricultural tools and machinery, namely the stages of cultivation, stripping, washing, stripping the horn skin, roasting, decomposing , labeling, and sealing. After knowing the amount of emissions produced, recommendations for alternative improvements are then made to handle the waste and reduce the magnitude of the impact which is symbolized in green.

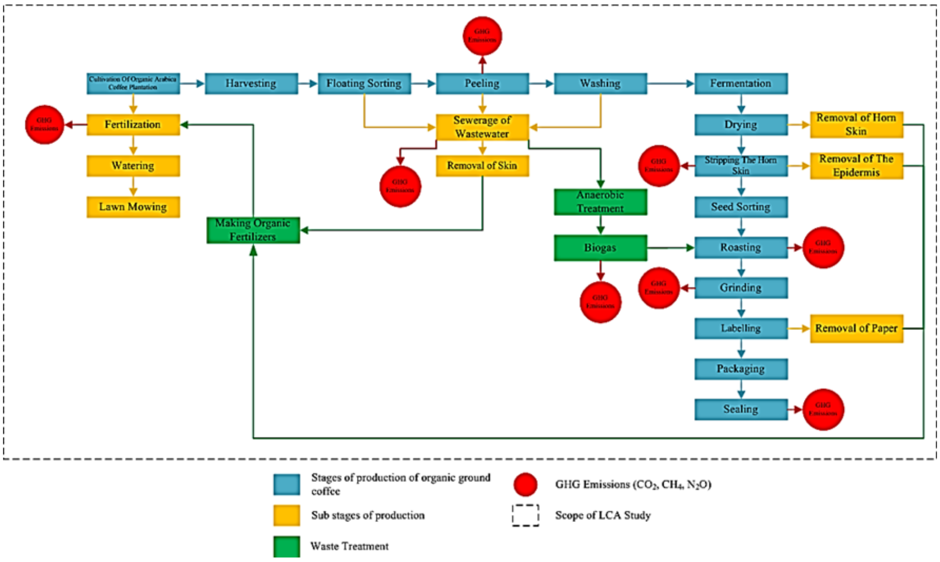


Figure 2. Details of the research scope

2.2.2 .Life Cycle Inventory (LCI)

LCI is carried out by taking an inventory of all input and output flows involved in units of mass and energy, especially direct energy (fuel and electricity consumption) per production process of organic Arabica coffee produced against greenhouse gas contributors from a predetermined scope. The following is the input-output mass and energy flow of the organic Arabica coffee production process presented in Tables 3 and 4.

Table 3. Inventory of organic Arabica coffee production processes

Input / Output	Amount	Unit	(%)	The most dominant process
Input : Main raw material				
Coffee beans (kg)	100.00	kg	100.00	Production process of Rambusa coffee
Input : supporting raw materials				
Water	517.75	kg	100.00	Production process of Rambusa coffee
Input : Electricity				
Platation Electricity	0.38	kWh	23.52	Fertilization process
Electric pascal harvest	1.25	kWh	76.48	Production process of Rambusa coffee
Input : Liquid fuels				
Gasoline	0.65	L	100.00	Production process of Rambusa coffee
Output : Main product				
Organic Arabica ground coffee	15.00	kg	100.00	Production process of Rambusa coffee
Output : Solid Waste				
Empty bean	12.80	Kg	14.10	Production process of Rambusa coffee
Coffee husk	60.00	Kg	66.12	Production process of Rambusa coffee
Dirt	1.40	Kg	1.54	Production process of Rambusa coffee
Weight loss	13.05	Kg	14.38	Production process of Rambusa coffee
Horn skin	0.60	Kg	0.66	Production process of Rambusa coffee
Broken green bean	1.00	Kg	1.10	Production process of Rambusa coffee
Water vapor	1.50	Kg	1.65	Production process of Rambusa coffee
Epidermis	0.40	Kg	0.44	Production process of Rambusa coffee

Tabel 4. Inventory of energy for organic Arabica coffee production

Activity	Inventori	Amount / production	Unit	Energy	Unit	Energy (MJ)	References
Fertilization	Electric *sprayer*	0.3840	Kwh	3.6	MJ/Kwh	1,382	(ESDM, 2018)
Peeling coffe bean	*Pulper machine* (gasoline)	0.0633	Liter	33.0	MJ/liter	2,090	Boer *et al.* (2012)
Stripping the horn skin	Mesin *huller* (bensin)	0.0868	Liter	33.0	MJ/liter	2,864	Boer *et al.* (2012)
Roasting	*Roaster* (LPG)	0.4967	Kg	47.3	MJ/Kwh	23,492	Boer *et al.* (2012)
	Electric *roaster*	0.1987	Kwh	3.6	MJ/kg	0,715	(ESDM, 2018)
Grinding	Electric *grinder*	0.4000	Kwh	3.6	MJ/Kwh	1,440	(ESDM, 2018)
Sealing	Electric *sealer*	0.6500	Kwh	3.6	MJ/Kwh	2,340	(ESDM, 2018)

2.2.3.Life Cycle Impact Assessment (LCIA)

At this stage an assessment of the results of the inventory that has been carried out is carried out. Assessment of the impact of all sources on the inventory resulting in an environmental impact category every time organic Arabica coffee is produced. The environmental impact categories used are the Global Warming Potential (GWP) or greenhouse gases (GHG) and energy use efficiency from the life cycle of organic Arabica coffee products. The total GHG emissions of organic Arabica coffee are calculated using the equation that refers to the IPCC guidelines (2006) in the book of Boer *et al.* (2012) as follows.

$$E = AD \times EF \qquad (1)$$

where E is GHG emissions (kg CO_2; kg CH_4; kg N_2O), AD is activity data (electricity in kWh; LPG, Gasoline, and Biogas in MJ; C-organic in kg), and EF is material emission factor (kg CO_2/AD; kg CH_4/AD; kg N_2O/AD). The emission factors for the materials used in this study are presented in Table 5. After calculating GHG emissions, it is continued by calculating the value of the environmental impact in the form of GWP, which is multiplying by the characterization factor in Table 6.

Table 5. Material emission factors

Inventory	Conversion factor			Referensi
	CO_2	CH_4	N_2O	
C-organic	3.6700000	-	-	(Maswar *et al.*, 2011)
Gasoline	0.0069300	0.0000300	0.0000006	(Boer *et al.*, 2012)
LPG	0.0631000	0.0000100	0.0000001	(Boer *et al.*, 2012)
Electricity	0.7743889	0.0000159	0.0000088	(Widyastuti & Nugrahayu, 2018)
Biogas	0.0546000	0.0000500	0.0000001	(KLHK, 2017)

Table 6. GWP characterization values

GHG Emission	Symbol	GWP (horizon 100 year)
Carbon dioxide	CO_2	1
Methana	CH_4	25
Dinitrogen okside	N_2O	298

Source : IPCC (2007)

The energy required (*En*) for each organic Arabica coffee production was calculated using the following equation.

$$En = n \times CV \qquad (2)$$

where *n* is inventory volume (MJ), and *CV* is calorfic value or energy conversion values (MJ/Kg).

Energy use efficiency was expressed in the form of unitless Net Energy Ratio (*NER*) and Net Energy Value (*NEV*) calculated using the following equations.

$$NER = \sum En_o / \sum En_i \qquad (3)$$

$$NEV = \sum En_o - \sum En_i \qquad (4)$$

where subscripts *o* and *i* referred to output and input, respectively.

3. RESULTS AND DISCUSSION

3.1. Determination of Mass Balance and Energy Balance

3.1.1. Life Cycle Inventory (LCI)

The Life Cycle Inventory (LCI) of organic Arabica coffee products in the Klungkung Coffee Agroindustry includes an inventory of organic coffee in plantations and post-harvest Arabica.

a. Organic Arabica Coffee Plantation Inventory

The organic Arabica coffee plantation is located in Klungkung Village (southern slope of the Argopuro Mountains of Jember). The cultivation and maintenance of organic Arabica coffee plantations is carried out by fertilizing, watering and cutting grass. The use of energy in garden maintenance can contribute to producing GHG emissions, namely the use of a sprayer machine in the fertilization process with energy input in the form of electrical energy. The type of fertilizer used is organic, because it is made by the farmers themselves in the form of powder and liquid fertilizers. Powder fertilizer is made from a mixture of manure, sawdust, and coffee husks as much as 1 to 1.5 tons for 1 ha of plantation. Liquid fertilizer is made from a mixture of coconut water and meat waste with a capacity of 756 kg for 1 ha of garden.

GHG emissions in organic Arabica coffee plantations can also be generated from the soil due to the use of organic fertilizers. The main source of GHG emissions from coffee cultivation comes from fertilizer management (Yulianingrum *et al.*, 2020). Emissions are taken into account in the form of soil C-organic, because it is in accordance with the purpose of this study which is to determine the feasibility of an organic Arabica coffee product that is environmentally friendly. In addition to soil C-organic data, supporting data is also used in the form of soil type and texture. Data on type, texture, and C-organic soil have a correlation which is used to determine how organic the soil is in organic Arabica coffee plantations and their effect on greenhouse gas emissions.

It is known that the soil type of organic Arabica coffee plantations is Latosol, the soil texture is clay loam (sandy loam) with an average amount of C-organic of 3.73%. The texture of the soil is said to be poor, because it contains only 38.1% sand. Good soil texture for Arabica coffee production is soil that contains >70% sand because it has the ability of the soil to store, conduct water and air, and provide plant nutrients (Efendi, 2020). Meanwhile, the amount of C-organic can be said to be sufficient to improve the chemical properties of the soil in the garden. This is because the C-organic content in the observed field is greater than the good C-organic requirement, which is 2% (Efendi, 2020).

b. Post Harvest Inventory of Organic Arabica Coffee

The following presents the mass balance of the post-harvest process of organic Arabica coffee in Figure 2. The most waste in the organic Arabica coffee production process is dirty water. So far, there has been no further processing of this waste (direct disposal). This of course can contribute to both the environment and GHG emissions. The high organic matter content in coffee processing wastewater will have a negative impact on reducing water quality so that further treatment is needed (Adinda, 2016).

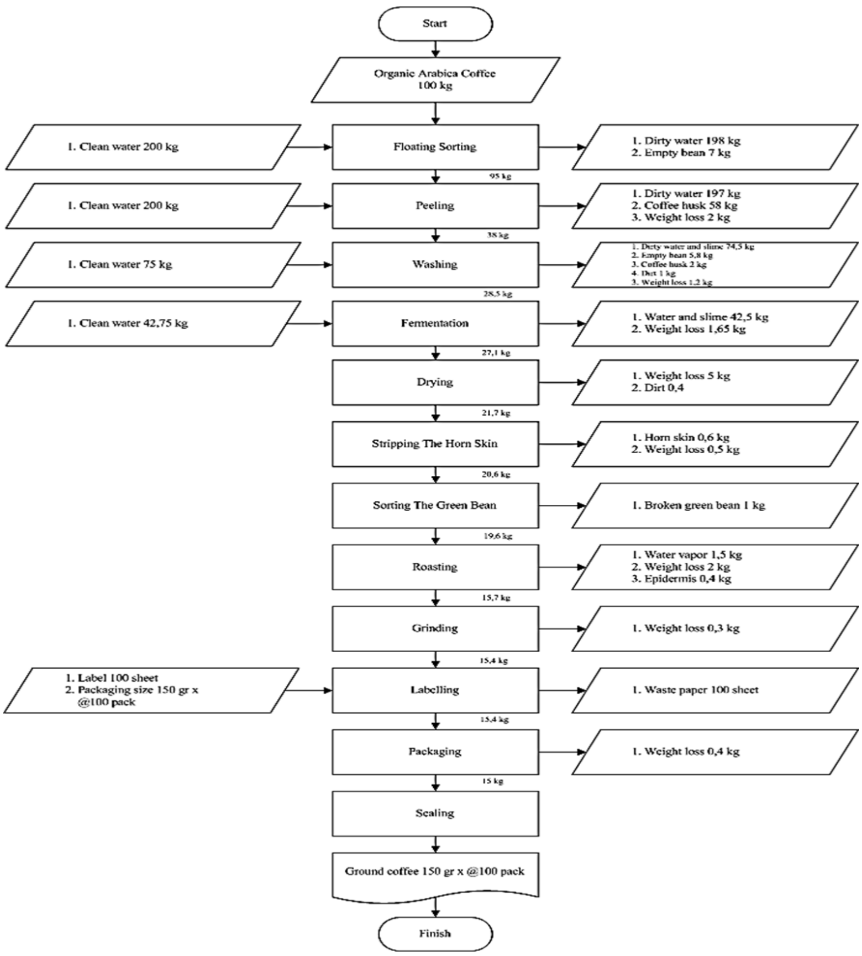


Figure 3. Mass balance of the post-harvest process of organic Arabica coffee

Therefore, to assess the impact later, it is necessary to know the COD value in the initial characteristics of organic Arabica coffee processing wastewater because the GHG emissions generated from organic Arabica coffee processing wastewater come from the COD number. The characteristic that determines the amount of emission in the form of CH_4 gas in industrial wastewater which is formed during the process of degradation of organic components or carbon contained in wastewater is the COD number (Ma'rufatin, 2016). The COD value of organic Arabica coffee wastewater is 1906 mg/L which exceeds the quality standard stipulated in the Regulation of Minister of Environment Number 5/2014 concerning wastewater quality standards for coffee processing businesses and/or industrial activities, which is 200 mg/L.

Nonetheless, greenhouse gas (GHG) emissions are also generated from tools and machines for the production of organic Arabica coffee. The use of production tools and machines certainly requires energy, both in the form of electricity and fuel. The increase in GHG emissions was due to growth in energy consumption which was dominated by electricity and fuel (Supriadi *et al*., 2016).

3.2. Environmental Impact Assessment

3.2.1. Calculation of GWP

The GWP or greenhouse gas emissions (GHG) produced in the organic Arabica coffee production process are presented in Table 7 and Figure 4.

Table 7. Total GWP or GHG emissions from organic Arabica coffee production

No.	Source of emission	Emission (kg $CO_{2\text{-eq}}$)		
		CO_2	CH_4	N_2O
1	Fertilization			
	a. Organic fertilizer	0.0137	-	-
	b. Electric Sprayer	0.2974	0.0002	0.0010
2	Manual watering	-	-	-
3	Manual weeding	-	-	-
4	Manual sortation by floating in water	-	-	-
5	Peeling (gasoline pulper machine)	0.0145	0.0016	0.0004
6	Wastewater from washing	-	15.2480	-
7	Manual fermentation	-	-	-
8	Manual drying	-	-	-
9	Gasoline for horn skin dehulling	0.0199	0.0021	0.0005
10	Manual green bean sortation	-	-	-
11	Roasting			
	a. LPG roaster	1.4825	0.0059	0.0007
	b. Electric roaster	0.1539	0.0001	0.0005
12	Electric grinding machine	0.3098	0.0002	0.0010
13	Manual labelling	-	-	-
14	Manual packaging	-	-	-
15	Electric sealing	0.5034	0.0003	0.0017
	Total	2.7948	15.2582	0.0059
	Total emission (kg $CO_{2\text{-eq}}$)		18.0589	

Based on the results of calculating the impact of GWP or GHG emissions shown in Table 7, it can be seen that the total emissions resulting from the production process of 100 kg of organic Arabica coffee become 15 kg of ground coffee (@150 grams x 100 packages) of the Rambusa brand in the Klungkung Coffee Agro-industry of 18 .0589 kg $CO_{2\text{-eq}}$ consisting of 2.7948 kg $CO_{2\text{-eq}}$ for carbon dioxide (CO_2) emissions, 15.2582 kg $CO_{2\text{-eq}}$ for methane (CH_4) emissions, and 0.0059 kg $CO_{2\text{-eq}}$ for nitrous oxide emissions (N_2O).

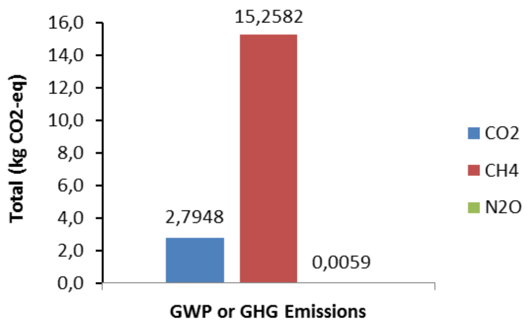


Figure 4. Total GWP or GHG emissions from organic Arabica coffee production

The overall emissions include exhaust gases originating from C-organic soil, the use of electrical energy in sprayer machines in the application of organic fertilizers in organic Arabica coffee plantations, the burning of gasoline and LPG fuel in the use of pulper, huller and roaster machines, the use of electrical energy in the use of machines roasters, grinders, and sealers, as well as organic Arabica coffee processing waste water. The biggest emission is CH_4 which comes from wastewater. This is because the emission factors for wastewater calculations are greater than the C-organic, fuel, and electricity emission factors. In addition, the GWP value of CH_4 is also greater than CO_2 but smaller than N_2O. However, in calculating wastewater emissions, N_2O is not taken into account because the calculation of wastewater N_2O is only in urban wastewater (Ma'rufatin, 2016).

3.2.2. Calculation of Energy Use Efficiency

The efficiency of energy use in LCA can be identified by measuring the net energy of the life cycle of organic Arabica ground coffee products. Net energy is the amount of energy needed and produced from a life cycle (Nugroho, 2014). The results of the calculation of input and output energy can be seen in Table 8, followed by the results of calculating the NEV and NER values to see the good efficiency of energy use in the life cycle of Arabica ground coffee products which are presented in Table 9.

Table 8. Comparison of input and output energy for processing 15 kg of ground coffee products

Input Energy	Fuel energy (MJ)	Electric energy (MJ)
Electric sprayer machine	-	1.38
Gasoline pulper machine	2.09	-
Gasoline huller machine	2.86	-
Roaster (LPG and electric)	23.49	0.72
Electric grinder machine	-	1.44
Electric sealer machine	-	2.34
Total (MJ)	28.45	5.88
Total Input Energy (MJ)	34.32	
Output Energy (Organic Arabica Coffee Ground, 15 kg)	1.20	

Table 9. Energy use efficiency for processing organic Arabica coffee ground (15 kg product)

Energy	Value
Input energy (MJ)	34.32
Output energy (MJ)	1.20
Net Energy Ratio	0.03
Net Energy Value	-33.12

The efficiency of energy use in the life cycle of a product can be said to be good if it has a NER value of more than 1 (one) and has a positive NEV value (Nugroho, 2014). Thus, the efficiency of energy use in the life cycle of Rambusa organic Arabica coffee products has not yet good.

3.3. Recommendations for Improvement Alternatives

The final step is to interpret the results of the impact analysis, so that an improvement process can be carried out from various alternatives to make the organic Arabica coffee product life cycle better from an environmental point of view. The recommended improvement alternatives are making coffee processing solid waste as organic fertilizer (compost) to reduce solid waste and add by-products to increase energy use efficiency, as well as anaerobic treatment of liquid waste to produce biogas as an alternative fuel for roasting to replace LPG and reduce greenhouse gas (GHG) emissions.

3.3.1. GHG Emissions with Improvement

If the improvement scenario is carried out by the Klungkung Coffee Agroindustry, then the GWP or GHG emissions generated in the life cycle of organic Arabica coffee products with the Rambusa brand are as follows presented in Table 10 and Figure 5.

Table 10. Comparison of GHG emissions (with and without improvement)

Source of Emission	Without Improvement			With Improvement		
	Emission (kg $CO_{2\text{-eq}}$)			Emission (kg $CO_{2\text{-eq}}$)		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Fertilization						
Organic fertilizer	0.0137	-	-	0.0137	-	-
Electric sprayer	0.2974	0.0002	0.0010	0.2974	0.0002	0.0010
Gasoline pulper machine	0.0145	0.0016	0.0004	0.0145	0.0016	0.0004
Wastewater from washing	-	15.2480	-	-	3.6557	-
Gasoline huller for horn skin	0.0199	0.0021	0.0005	0.0199	0.0021	0.0005
Roasting						
LPG roaster	1.4825	0.0059	0.0007	-	-	-
Biogas roaster	-	-	-	1.3668	0.0063	0.0007
Electric roaster	0.1539	0.0001	0.0005	0.1539	0.0001	0.0005
Electric grinder machine	0.3098	0.0002	0.0010	0.3098	0.0002	0.0010
Electric sealer machine	0.5034	0.0003	0.0017	0.5034	0.0003	0.0017
Total	2.7948	15.2582	0.0059	2.6792	3.6663	0.0059
Total Emission (kg $CO_{2\text{-eq}}$)	18.0589			6.3514		
Emission Difference (kg $CO_{2\text{-eq}}$)	11.7075					
Decreament (%)	64.8295					

Based on Table 10, it is known that the change in emissions lies in the washing and roasting processes. The washing process, which originally resulted in emissions of 15.2480 kg $CO_{2\text{-eq}}$, decreased to 3.6557 kg $CO_{2\text{-eq}}$ due to the anaerobic handling of liquid waste into biogas, while the roasting process experienced a decrease in the share of LPG emissions, which was originally 1.4891 kg $CO_{2\text{-eq}}$ to 1.3738 kg $CO_{2\text{-eq}}$ due to replacement of LPG with biogas.

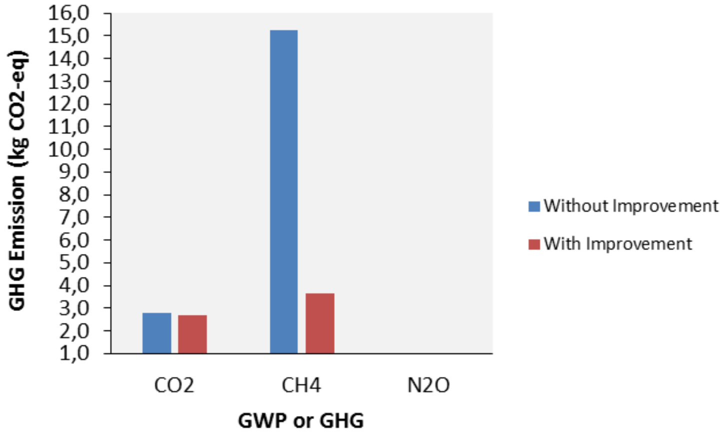


Figure 5. Comparison of GWP or GHG emissions

Based on Table 10, it is known that a significant reduction occurred in emissions generated by post-harvest processing wastewater of organic Arabica coffee. This is because wastewater that has been carried out by an anaerobic process will contain a low COD value, so that it is directly proportional to the emissions produced. One alternative utilization of by-products that provides benefits in meeting fuel or energy needs is biogas (Novita, 2012), so that, in this alternative improvement scenario, biogas produced from anaerobic waste water treatment is used as a substitute fuel for LPG in the roasting process.

3.3.2.. Energy Use Efficiency with Improvement

Based on the alternative improvement scenarios provided, the Klungkung coffee agro-industry can produce additional output energy in the form of organic fertilizer and biogas. The following comparison of input and output energy before and after improvement can be seen in Table 11, followed by a comparison of NEV and NER values to see the good efficiency of energy use in the life cycle of Arabica ground coffee products after the improvement which is presented in Table 12.

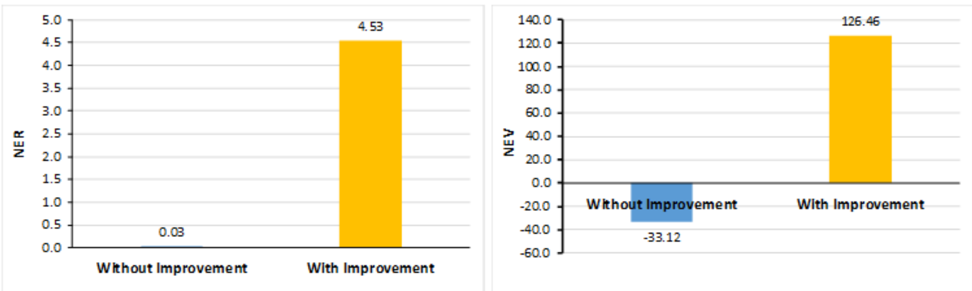
Based on Table 11, it can be seen that if alternative improvement scenarios are carried out in the life cycle of organic Arabica coffee products in the Klungkung Coffee Agro-industry, energy use efficiency can be said to be good. This is evidenced by the NER value indicating more than 1 and the NEV value indicating a positive value. This is in accordance with Nugroho (2014) that energy efficiency in the life cycle of a product can be said to be good if it has a NER value of more than 1 (one) and has a positive NEV value. Comparison of NER and NEV before and after repairs can be seen in Figure 6.

Table 11. Comparison of input and output energy with and without improvement

Input Energy	Without Improvement		Without Improvement	
	MJ	Persentage (%)	MJ	Persentage (%)
Sprayer machine	1.38	4.03	1.38	3.85
Pulper machine	2.09	6.09	2.09	5.83
Huller machine	2.86	8.35	2.86	7.99
Roaster machine	24.21	70.53	25.75	71.79
Grinder machine	1.44	4.20	1.44	4.02
Sealer machine	2.34	6.82	2.34	6.52
Total Input Energy (MJ)	34.32	100.00	35.86	100.00
Output Energy	**Without Improvement**		**Without Improvement**	
	MJ	**Persentage (%)**	**MJ**	**Persentage (%)**
Organic Arabika coffee ground (15 kg)	1.20	100.00	1.20	0.74
Organic fertilizer (104.71 kg)	0.00	0.00	99.65	61.39
Biogas (1.22 kg)	0.00	0.00	61.48	37.87
Total Output Energy (MJ)	1.20	100.00	162.33	100.00

Table 12. Comparison of energy use efficiency with and without improvement

Energi	Without Improvement	Without Improvement
	Value	Value
Input energy (MJ)	34.32	35.86
Output energy (MJ)	1.20	162.33
Net Energy Ratio (NER)	0.03	4.53
Net Energy Value (NEV)	-33.12	126.46



(a) (b)

Figure 6. Comparison of energy use efficiency parameters: (a) NER, and (b) NEV

Based on Figure 6. It is known that the NER and NEV values before and after the improvement alternatives have increased and have a positive value. The NER value which was previously 0.03 increased to 4.53 and the NEV value which was previously -33.12 increased to 126.46. This is due to the addition of product output in accordance with the recommendations, namely in the form of organic fertilizer and biogas.

4. CONCLUSIONS AND SUGGESTIONS

4.1. Conclusion

Based on the results and discussion, several conclusions can be obtained, including the mass balance of organic Arabica coffee products in the Klungkung coffee agro-industry consisting of plantation processes and post-harvest processes that begin with an input of 100 kg of coffee beans resulting in an output of ground coffee of 15 kg (100 packs @150 grams). While the energy balance of organic Arabica coffee products consists of direct energy use of fuel and electricity in the sprayer, pulper, huller, roaster, grinder and sealer processes. The environmental impact generated in each life cycle process of organic Arabica coffee products in the Klungkung coffee agro-industry consists of a global warming potential (GWP) of 18.0589 kg $CO_{2\text{-eq}}$/15 kg ground coffee and energy use efficiency per 15 kg ground coffee which includes the value NER is equal to 0.03 and NEV is equal to -33.12. Alternative recommendations for improving the production process to reduce environmental impact on the Klungkung coffee agro-industry are in the form of utilizing coffee processing solid waste as organic fertilizer (compost) and anaerobic treatment of liquid waste to produce biogas.

4.2. Suggestion

It is hoped that in future research, a test for the content of organic fertilizers made by agro-industry parties will be carried out to determine the NPK content which can be used as material for calculating the resulting environmental impact in the form of greenhouse gas emissions. In addition, it is also hoped that in future research, emission calculations with other impact categories will be carried out.

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