Environmental Analysis of Coffee Production in Jember

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Abstract. Jember Regency is one of the districts which is the center for the cultivation and development of coffee in East Java. The objectives of this research are determining the environmental impact and provide alternative recommendations for process improvement. Life Cycle Assessment is used to calculate the environmental impact of ground coffee production). This research calculates energy consumption per 1 kg of coffee cherries and GHG emissions per year coffee production. The scope of this research is carried out from production to the packaging process (gate to gate). The ground coffee production consumed 0.27 MJ/kg and 0.74 MJ/kg for Arabica and Robusta, respectively. The highest energy consumption and emission generated are from the roasting process. The emission of ground coffee industries contributed to global warming potential 253.77 kg CO2-eq and 16.79 kg CO2-eq for Ketakasi and Madu Kembang product, respectively. To reduce the GWP contribution, switching the fossil fuel to biodiesel fuel is a possible option.

Keywords: LCA, Coffee Production, Environment, GWP.

1 Introduction

Robusta coffee is a descendant of several coffee species, especially Coffea canephore. This type of coffee grows well at an altitude of 400-700 m above sea level, temperature 21-24°C (UCDA, 2019). The quality of Robusta coffee is mostly lower than Arabica and Liberica. Robusta coffee tastes like chocolate, is more bitter and slightly sour, and has a distinctive and sweet aroma. The taste of Robusta coffee is generally considered lower than arabica coffee, so the price of Robusta coffee tends to be cheaper than arabica coffee. Because of these lower prices, farmers more often process Robusta coffee using the dry method because of the lower cost. This method is known as the natural process [8]. Arabica coffee processing can be done using other methods such as full-washed and semi-washed.

Jember Regency is one of the districts which is the largest center for smallholder coffee cultivation and development in East Java. In 2022, people's coffee production will reach 4193 tons with a plantation area about 6442.45 ha [1]. Processing coffee cherries into ground coffee dominated by small and medium scale industries such as the Ketakasi Coffee Cooperative which processes Robusta coffee from the mountain slope Gumitir and the Rumah Kopi Banjarsengon (RKB) which processes Arabica coffee from slope mountains Argopuro. Both industries are using natural processes to make ground coffee.

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The industrial competition leads to a green industry. The coffee industries in Jember Regency must adapt with implementation of environmentally friendly processing. Therefore, they need to assess their processing line. Life Cycle Assessment is a comprehensive method to evaluate the processing line for agroindustry [5][2].

2 Materials and Methods

Materials
For data collection, a camera is used for documentation and observation research, the calculator is used to calculate the mass of environmental impacts in the form of emissions, direct energy, and energy efficiency. For proper calculation, a laptop is used to carry out inventory, create mass and energy balances with software Ms. Excel. The products for this evaluation are Robusta ground coffee and Arabica ground coffee products packaged in 250 grams (Ketakasi Coffee) and 500 grams (RKB Coffee).

Research Stages
This study was conducted in several stages in accordance with ISO 14040 standard on LCA. The stages in question are (1) determining goals and scope, (2) Life Cycle Inventory Analysis (3) Life Cycle Impact Assessment Analysis and final stage (4) Interpretation.

At stage determination *goals and scope* determined the limitation coffee life cycle that is *gate to gate* that started from the process of receiving coffee cherries until downstream product ground coffee with packaging 250 grams and 500 grams. These ground coffees are appropriate products produced by the small and medium coffee industry in Jember. For the function unit used is per kg coffee cherries.

The Life Cycle Inventory stage is carried out with input and output values of the ground coffee production process. This calculation is done by conversion process or direct measurement. Factor conversions and factors emission used to calculate the amount of energy input and emission output generated.

Life Cycle Impact Assessment Analysis Stage refers to the Guidelines Drafting Report Evaluation Cycle Life (LCA) in 2021 published by the Directorate General Control Pollution and Environment, Ministry of Environment and Forestry. There are 5 main parameters measured (if data is available), those are consumption energy, potential global warming, acidification, eutrophication, and ozone depletion potential.

The interpretation stage is carried out by evaluating stages that have the potential to use high energy and produce the largest emissions. Then, an analysis is carried out to reduce energy use or emissions qualitatively using references.

Analysis Method
Obtained data was analyzed quantitatively using emission factors and conversion factors. Meanwhile, recommendations for improvement are carried out qualitatively using existing references. Energy demands are calculated using these Equations:

$$\text{Total Energy: } E_e + E_L + E_f \quad (1)$$

$$E_e = P \times t \times Cf \quad (2)$$

E_e : Energy from Electricity (MJ)
P : Power (Watt)
t : Time (hour)
Cf : Conversion factor (3.6 MJ/Kwh)

$$E_L = n \times Cf \times t \quad (3)$$

EL : Energy from Labor
N : number of labor
Cf : Conversion factor (0.79 MJ/h)
t : activity time (hour)

$$E_f = v \times Cf \quad (4)$$

Ef : Energy from Fossil Fuel
V : volume
C_f: Conversion factor

Emission generated during process are calculated using formula:

$$\text{Emission} = \text{Fuel Consumption} \times \text{Emission Factors} \quad (5)$$

3 Result and Discussion

The coffee products as objects of this research are the products with brands Ketakasi and Madu Kembang (Fig.1). The amount for one process for Ketakasi coffee cherries is 200kg while for flower honey it is 300kg.

Fig 1. Ketakasi and Madu Kembang Ground Coffee

Life Cycle Inventory (LCI)
Robusta coffee processing is carried out using the natural process method. The inputs for the Robusta coffee production process consist of Robusta coffee beans, label paper and packaging. The process output consists of ground coffee, coffee skin, weight loss, horn skin, broken green beans, steam, and epidermis. Greenhouse gas (GHG) emissions result from the use of production tools and machines. Emissions have

increased due to growth in energy consumption which is dominated by electrical energy and fuel [10]. Meanwhile, the flow of Arabica coffee includes sorting the beans, drying, stripping the skin (hulling), sorting the beans (size grading), roasting, pulverization (grinding), packaging, labelling, and sealing which is packaged using 500g and 250g packaging. The differences in processing processes can be seen in Fig. 2.

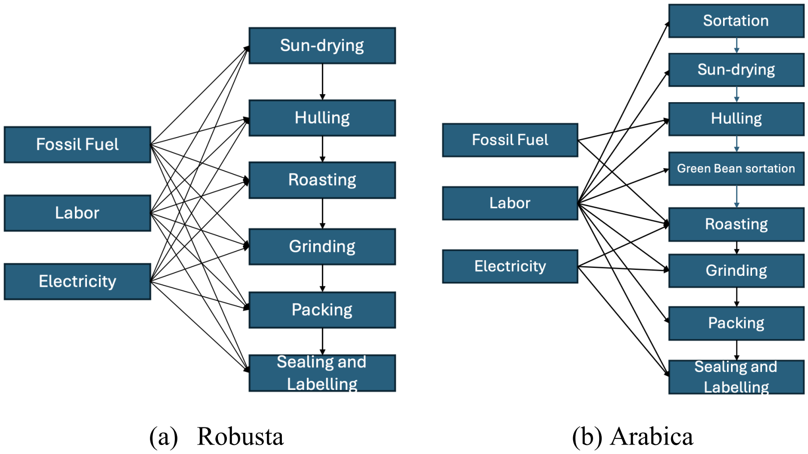

Fig. 2. Comparation process of Robusta coffee and Arabica coffee

Energy and Emissions of Ground Coffee Production

Based on the amount of fuel consumed, the number of emissions that will be produced can be calculated for the Life Cycle Impact Assessment (LCIA) stage.

Table 1. Factor conversion of energy

Energy sources	Energy	Unit	Reference
Fuel	33,0	MJ/litre	Boer dkk. (2012)
Diesel Fuel	36,0	MJ/litre	Boer dkk. (2012)
LPG	47,3	MJ/Kg	Boer dkk. (2012)
Electricity	3,6	MJ/ Kwh	Ministry of Energy and Mineral Resources (2018)

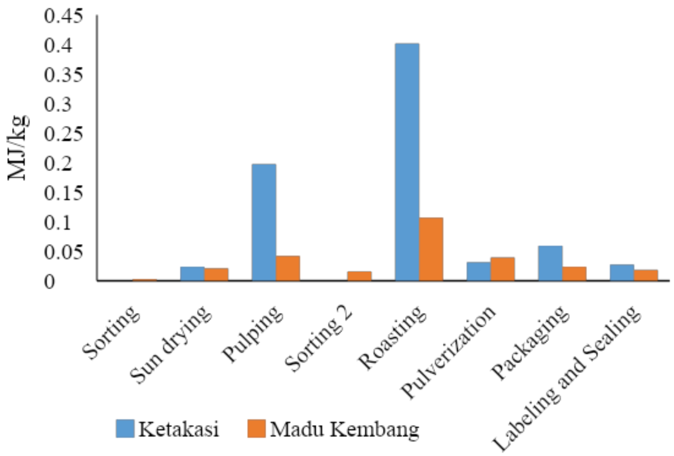

Fig 3. Energy demand for 1 kg coffee cherries

Based on Fig.3, it can be explained that the largest energy use is in the roasting process. This process uses electrical energy sources and fuel. In the Ketakasi industry, the heating system in this roaster is carried out using a conduction process by connecting the flame source directly from LPG to the rotating cylinder so that the rotating cylinder experiences an increase in temperature and then transfers heat from the rotating cylinder to the coffee. The capacity of the roasting machine used is 12 kg/hour with an electrical power requirement of 120 watts and LPG fuel of 0.3 kg/hour. The results that can be obtained from using a coffee roaster with a closed cylinder model and at high temperatures can roast quickly. Besides that, the coffee that has been roasted is dark roast [12]. Meanwhile, in the RKB industry, the Roaster used has a capacity of 12 kg/hour with an electric power of 120 watts and fuel consumption of 0.54 kg/hour. The Arabica coffee roasting process takes 10 minutes. The roasting process is carried out by inserting green beans into the machine cylinder which produces a product output in the form of roast beans (roasted coffee beans). The efficiency of using a roasting machine at the Ketakasi Cooperative is lower than RKB, this can be seen from the large amount of energy used in the roasting process with the same machine.

Gas emissions resulting from the coffee processing process come from 2 main sources, namely the use of electrical energy and fossil fuel energy. Total emissions of CO_2 for Ketakasi and Kembang Madu are 35.78 g/kg and 16.57 g/kg respectively. Emission of CH_4 and N_2O for Ketakasi and Kembang Madu are 0.005g/kg; 0.004g/kg CH_4 and 0.0025g/kg; 0.0004g/kg N_2O, respectively. The emissions of each process are shown in Fig. 4.

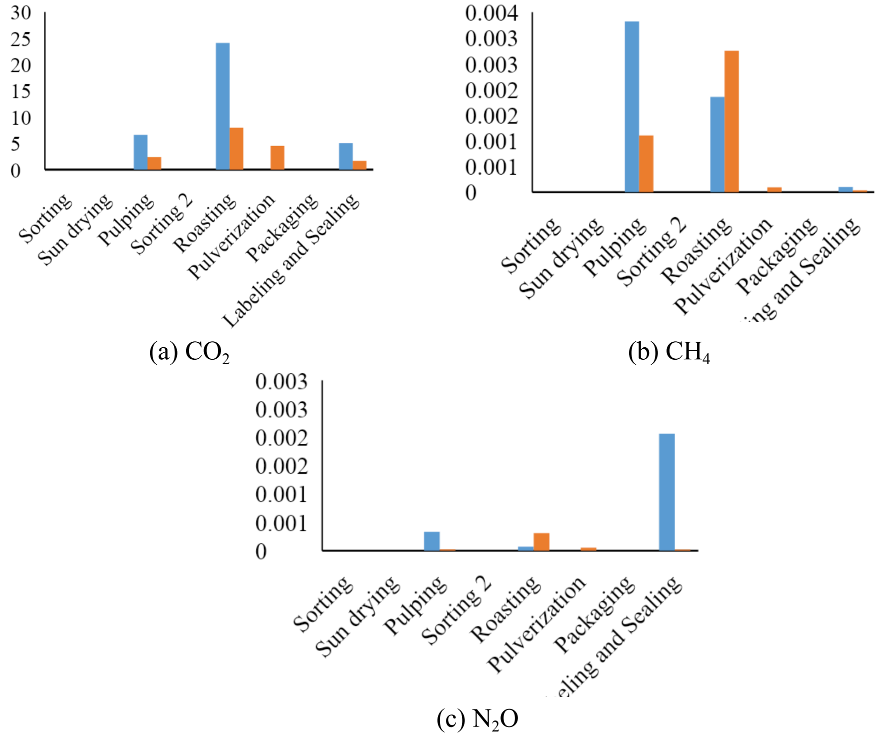

Fig 4. Emission (gram) of CO_2, CH_4 and N_2O for each kg coffee cherries

Based on the results of emission calculations, the highest emissions produced are carbon dioxide (CO_2). All gas emissions emitted from burning in the use of huller and roaster machines. The use of electrical energy in the use of roaster, grinder, and sealer machines. Once the total emissions produced identified, emissions will be calculated for one year as environmental impact. The Kertakasi Cooperative produces 6 tons of coffee in 1 year, while for RKB it produces 1 ton.

Life Cycle Impact Assessment (LCIA)

Based on the results of the analysis of the emissions produced, the environmental impact analyzed is only Global Warming Potential. The GWP impact is obtained from calculating the amount of greenhouse gases, namely CO_2 equivalent which comes from CO_2 and other gases. GWP calculations can be done over a certain period such as 1 year, 25 years or 100 years. Conversion of N_2O and CH_4 gas into CO_2 equivalent based on Table 2.

Table 2. Factor Conversion of GWP

No	Emisi	GWP
1	CO_2	1
2	N_2O	25
3	CH_4	298

The magnitude of the GWP impact on coffee production at the Ketakasi Cooperative and Banjarsengon Coffee House is as follows:

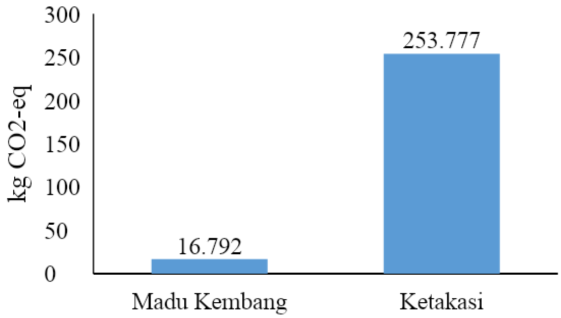

Fig 5. GWP per year of Madu Kembang and Ketakasi production

Based on Figure 5, we can see that the production of Ketakasi Robusta ground coffee produces a much greater GWP than Madu Kembang produced at RKB. This is due to the significant difference in the amount of coffee produced in the two industries. Robusta coffee production in Jember district is greater than Arabica coffee. GWP is caused using fossil fuels, gas and electrical energy which is quite high[4].

Interpretations

After determining the goals and targets to overcome the problems that occur in the company, the next step is to prepare alternative solutions which aim to solve the problems that occur where in the Ketakasi and RKB industries the coffee production process produces high emission values, namely in the roasting process. In the roasting process, it is necessary to check the equipment regularly so that the machine becomes efficient. Apart from that, a recommendation that can be given to reduce these emissions is the use of biodiesel as a fuel substitute. Biodiesel is a fuel made from vegetable oil which has properties similar to diesel oil. This fuel is environmentally friendly because it produces lower gas emission than fossil fuel. Biodiesel is known as an environmentally friendly fuel because it is renewable and produces cleaner exhaust emissions compared to diesel oil. It releases a lower hydrocarbon and carbondioxide [7]. The exhaust gas from biodiesel combustion that is released into the atmosphere will be reabsorbed by plants for the photosynthesis process. Biodiesel will reduce exhaust emissions without sacrificing engine performance and efficiency [3][6].

4 Conclusion

The production process for Robusta and arabica coffee released quite large emissions, 0.27 MJ/kg and 0.74 MJ/kg coffee cherries, or 0.97 MJ/pcs 250g Robusta ground coffee and 0.23 MJ/pcs 500g arabica ground coffee. The total global warming potential of Ketakasi Coffee and Madu Kembang Coffee are 253.77 kg CO_2-eq and 16.79 kg CO_2-eq, respectively. Biodiesel can substitute the fossil fuel to achieve lower emissions and GWP.

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