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The Importance of LCA in the Production of Turmeric Powder And Chilli Powder at PT X

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Abstract. PT X is one of the businesses in Indonesia that deals with food, particularly spices. The seasoning sector is growing because its existence is becoming more and more expected. Of course, energy and emissions will not be separated from the process of generating spices, especially when producing powdered spices. According to government policy, the sector is supposed to develop into one that is sustainable and environmentally friendly. The Life Cycle Assessment is a common environmental impact assessment (LCA). A method called life cycle analysis (LCA) is used to evaluate a product system's sustainability advantages over the course of its life. This study's goal is to use the LCA approach to examine how much energy and material are consumed, as well as emissions and potential environmental effects, during the production of seasoning powder at PT X. Establishing the goals and scope, inventory analysis, environmental impact analysis, and interpretation are the four processes utilized in the LCA. The study's findings show that 7,963 MJ are needed to manufacture 1 kilogram of turmeric powder, with a potential environmental impact of GWP 0.7627 kg CO2 –eq, AP 0.7796 x 10-4 kg SO2 –eq, and EP 0.528 x 10-4 kg N-eq. Chili powder, on the other hand, uses 8,506 MJ and have an environmental impact of GWP 0.8418 kg CO2 –eq, 0.8690 x 10-4 kg SO2 –eq, and 0.664 x 10-4 kg N –eq.
Keywords: Emission, Energy, Life Cycle Assessment (LCA)

1 Introduction

PT X is a medium-sized business that manufactures spices and seasonings for the food industry. (Badan Pusat Statistik 2021) estimates that there will be 29,000 medium- and large-scale industries in 2021. Because spices are the fundamental components of cooking, which are fundamental necessities of the community, the potential of various spices in Indonesia makes this company see an opportunity. With a total of 280 different product categories, PT X has a production capacity of about 3000 tons per month. The manufacturing is split up into three separate units and stored in a single storage unit, with unit 1 producing an average of 800 kg every shift of powdered spices.

Due to several production procedures, the increasing demand for powdered spices at PT X has a detrimental effect on the environment. A technique known as Life Cycle Assessment can be used to evaluate the production process's overall environmental impact (LCA). LCA is the collection and assessment of inputs, outputs, and potential environmental impacts of a product system over the entirety of its life cycle [4]. According to some sources, LCA is a method that consists of four stages: establishing the scope, cataloguing inputs and outputs, analysing environmental consequences, and interpreting the outcomes of the inventory analysis from the stage before [8]. Due to differences in the production process, this LCA study will focus on items containing turmeric and chili powder, and the results cannot be used to evaluate the environmental impact of other products in PT X. The LCA assessment uses four scopes that act as system boundaries. The four scopes that [9] wrote are as follows:

1. Cradle to grave refers to a life cycle assessment that is completed from the time that raw materials are taken until all materials are recycled back into the earth.
2. Cradle to gate, its scope consists of completed goods from the collecting of raw materials through to their distribution to customers.
3. Gate to gate, which simply evaluates the product life cycle on procedures that have added value, is the shortest scope of the other four.
4. Cradle to cradle examines the life cycle of a product from raw materials to material recycling.

This study's goal is to evaluate the effects of turmeric powder and chili powder products on the environment from gate to gate, as previously described. The following potential environmental effects will be evaluated:

1. Global Warming Potential (GWP)

GWP, often known as global warming, is an environmental effect that raises the Earth's temperature [3]. The volume of CO2 emissions emitted into the atmosphere is one of the main causes of GWP.

2. Acidification Potential (AP)

The process of acidic pollutants being deposited in soil, water, surface organisms, biological, and subsurface water is known as "acidification potential," or AP [2]. High amounts of sulphur oxides and nitrogen oxides contribute to acidification.

3. Eutrophication Potential (EP)

Increasing water productivity by EP results in an environmental imbalance that can lower water quality. According to Eyre & Lester (2002) in Mukhtasor (2007) in [10] eutrophication is brought on by the presence of phosphate and nitrogen waste that enters the waters and creates aquatic plant blooms as well as a decrease in the amount of dissolved oxygen in the water.

2 Research Methods

The forms of data used in this study comprised primary data and secondary data, and it was carried out in a company in Cilowa, Kuningan Regency, West Java, over the course of a month in unit 1 of PT X.

3 Collection of Data

Three types of data were collected for this study: primary data were obtained through observation to understand the production process; secondary data came from literatures drawn from various journals and associated sources; and thirdly, primary data were obtained through interviews.

3.1 Life Cycle Assessment

The LCA assessment is divided into the following four stages:

1. Determining the LCA's Scope

   The research is conducted when purchasing raw materials to turn into goods before being delivered, and its scope is gate to gate.

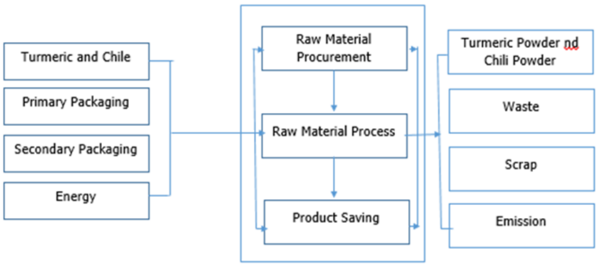

Figure 1. Study's LCA Scope

2. Product Life Cycle Inventory

   The energy used in the production process is computed at the inventory stage, followed by the total emissions for each gas under consideration. The following formula will be used to multiply a conversion factor by each gas under study:

   Total Emissions = Energy Consumption x Conversion Factors

3. Product Life Cycle Impact Analysis

   Three steps make up the impact assessment, the first of which classifies the researched gases according to their potential effects on the environment. The characterisation step is converted into a weighted value using the environmental impact indicator's conversion value, and the assessment stage is converted into a quantitative total by dividing the conversion factor by the quantity of pollutants. The corresponding value utilized alludes to the information in [7].

4. Interpretation of the Product Life Cycle

   Determining whether the calculated environmental impact exceeds the quality standard threshold or not and offering recommendations.

4 Result and Discussion

Based on the research's results, the 400 kg production process for turmeric powder generated 388 kg of products with emissions and scrap output and the 400 kg production process for chili powder produced 382 kg with emissions and scrap output. The elements used to produce chili powder and turmeric powder are listed in Table 1. The production process generates output in addition to the inputs indicated in table 1 in the form of flue gas, solid waste in the form of plastic (each operation generates plastic since it needs to be replaced with new packaging), and scrap.

The total energy listed in table 2 is generated by calculating the type of energy input used. It can be shown that producing 1 kg of turmeric powder requires a total energy of 7.693 MJ, whilst producing 1 kg of chili powder requires a total energy of 8.506 MJ. The largest energy used in the production of both turmeric powder and chili powder is fuel energy used to purchase raw materials and packaging materials. Figure 1 shows that up to 44% of the energy input utilized for turmeric powder and up to 37% of the energy input required for chili powder both come from fuel.

Table 1. Process Production Input

Process	Energy Input Type	
	Turmeric Powder	**Chili Powder**
Raw Material Procurement	People, FUEL (solar)	Raw Material Procurement
Packaging Procurement	People, Electricity	Packaging Procurement
Stripping	People, Electricity	Stripping
Grinding	People, Electricity	Grinding
Sifting	People, Electricity	Sifting
Mixing 1	People, Electricity	Mixing 1
Mixing 2	People, Gas, Electricity	Mixing 2
Oven	People, Electricity	Oven
Cooling	People	Cooling

The amount of energy used in each step of the manufacturing of chili powder and turmeric powder is the basis for the study of emission calculations. The emission gases examined in this study are CO2, CH4, N2O, SO2, CO, and NOX, with each emission gas being classified according to the study's three environmental implications. The results of converting each total energy into a corresponding emission value are shown in Table 3. Of all the gas emission values, CO¬2 has the highest emission value. Due to the distance between the supplier and the manufacturer, energy from gasoline generates the most CO2 emissions, necessitating a lot of fuel for both goods to be purchased as raw materials. High fuel and electrical energy use results in high emission values.

Table 2. Total Energy for Turmeric Powder and Chili Powder

Process	Total Energy Released (MJ)							
	Turmeric				Chili			
	People	**Electricity**	**Gas**	**Fuel**	**People**	**Electricity**	**Gas**	**Fuel**
Raw Material Procurement	17.64	-	-	758.781	17.64	-	-	597.55
Packaging Procurement	17.97	-	-	614.688	17.97	-	-	605.178
Stripping	2.94	2.686	-	-	2.94	2.685	-	-
Grinding	3.36	644.544	-	-	47.04	966.816		-
Sifting	11.76	37.598	-	-	11.76	32.227	-	-
Mixing 1	0.65	4.485	-	-	0.65	4.485	-	-
Mixing 2	1.29	8.862	-	-	0.98	8.862	-	-
Oven	3.92	10.742	913.77	-	3.92	10.742	913.77	-
Cooling	1.31	3.599	-	-	1.31	3.599	-	-
Packing	1.64	-	-	-	1.64	-	-	-
Total/1x Production	**90.49**	**712.516**	**913.77**	**1373.465**	**105.86**	**1027.269**	**913.77**	**1202.729**
Total Production (kg)	**388**				**382**			
Total/1 kg product	**0.233**	**1.836**	**2.355**	**3.539**	**0.277**	**2.689**	**2.392**	**3.148**
Total Energies/1 kg Product	**7.963**				**8.506**			

Table 3. Emission Released

Emission	Emission released/ kg product (kg)					
	Turmeric			Chili		
	Electricity	**Fuel**	**Gas**	**Electricity**	**Fuel**	**Gas**
CO_2	0.249	0.2623	0.149	0.364	0.2333	0.151
CH_4	0.178×10^{-3}	0.1380×10^{-4}	0.235×10^{-5}	0.261×10^{-3}	0.1227×10^{-4}	0.239×10^{-5}
N_2O	0.780×10^{-6}	0.1380×10^{-4}	0.235×10^{-6}	0.114×10^{-5}	0.1227×10^{-4}	0.239×10^{-6}
SO_2	0	0.0297	0.118×10^{-5}	0	0.0264	0.119×10^{-5}
CO	0.255×10^{-4}	0.1167×10^{-4}	0.118×10^{-3}	0.373×10^{-4}	0.1038×10^{-4}	0.119×10^{-3}
NO_x	0.612×10^{-4}	0.471×10^{-9}	0.118×10^{-3}	0.894×10^{-4}	0.419×10^{-9}	0.119×10^{-3}

The computed emissions are then divided into estimates of the three potential environmental effects, namely acidification, eutrophication, and global warming. Table 4 displays the classification of emissions into environmental impacts. Acidification will be equivalent to SO2 –eq, eutrophication will be equivalent to N-eq, and global warming will be equivalent to CO2 –eq in terms of potential environmental effects.

Table 5 provides a quantitative analysis of the three environmental impacts' possible values, which have been compared using equivalent values. With 0.7627 kg CO2 –eq of turmeric powder, GWP has the highest potential environmental effect value, followed by AP (0.7796 x 10-4 kg SO2 –eq) and EP (0.58 x 10-4 kg N –eq). With a value of 0.8418 kg CO2 –eq, chili powder's GWP value likewise has the highest possible environmental effect value. This is followed by AP values of 0.8690 x 10-4 SO2 –eq and EP values of 0.664 x 10-4 kg N –eq. Because both products require a lot of fuel, which results in a lot of CO2 emissions, which are the primary indication of global warming, the high GWP number is caused by this.

Table 4. Emission Classification of Environmental Impact Potential

Emission	Environmental Impact		
	Global Warming	**Acidification**	**Eutrophication**
CO_2	✓		
CH_4	✓		
N_2O	✓		✓
SO_2		✓	
CO	✓		
NO_x		✓	✓

Table 5. Potential Value of Environmental Impact

Environmental Impact Potential	Emission	Potential Value kg – eq.	
		Turmeric powder	Chili powder
GWP (CO_2 –eq)	CO_2	0.6620	0.7485
	CH_4	0.6620 x 10^{-2}	0.9388 x 10^{-2}
	N_2O	0.4417 x 10^{-2}	0.4071 x 10^{-2}
	CO	0.8963 x 10^{-1}	0.7981 x 10^{-1}
	Total	**0.7627**	**0.8418**
AP (SO_2 –eq)	SO_2	0.650 x 10^{-4}	0.7532 x 10^{-4}
	NO_x	0.1287 x 10^{-4}	0.1158 x 10^{-4}
	Total	**0.7796 x 10^{-4}**	**0.8690 x 10^{-4}**
EP (N –eq)	N_2O	0.542 x 10^{-4}	0.627 x 10^{-4}
	NO_x	0.400 x 10^{-5}	0.368 x 10^{-5}
	Total	**0.582 x 10^{-4}**	**0.664 x 10^{-4}**

The emission values and potentials created during the production of turmeric powder and chili powder can still be considered acceptable because they are lower than the thresholds established by the [5] and [6] Patent 41. Table 6 shows the quality standard threshold for emission values. The emission value obtained is still below the quality level, as shown in quality standard table 6.

Table 6. Comparison of Thresholds

Product	**Parameter**	**Emission**		**Threshold (ppm)**	**Description**
		kg/kg	**ppm**		
Turmeric powder	CO_2	0.662	1.706 x 10^3	40000	below the limit
	CH_4	0.194 x 10^{-3}	0.501	10000	below the limit
	N_2O	0.148 x 10^{-4}	0.038	50	below the limit
	SO_2	0.128 x 10^{-4}	0.033	365	below the limit
	CO	0.298 x 10^{-1}	77.010	10000	below the limit
	NO_x	0.180 x 10^{-3}	0.466	150	below the limit
Chili powder	CO_2	0.748	1.959 x 10^3	40000	below the limit
	CH_4	0.276 x 10^{-3}	0.723	10000	below the limit
	N_2O	0.136 x 10^{-4}	0.036	50	below the limit
	SO_2	0.116 x 10^{-4}	0.030	365	below the limit
	CO	0.266 x 10^{-1}	69.644	10000	below the limit
	NO_x	0.209 x 10^{-3}	0.547	150	below the limit

Although the obtained emission value is still within the quality standard threshold, but the CO2 value is quite high, it is required to reduce energy use, which generates high emissions. PT X can make recommendations such as limiting the frequency of shipments, with each cargo carried out at full capacity, seeking for alternative suppliers that are closer to the factory, and doing intensive maintenance every week. According to the literature, employing an Integrated Gasification Combined Cycle (IGCC) power plant, which mixes coal and Gas Turbine Combined Cycle (GTCC), can replace the usage of electrical energy [11]. The IGCC system has the ability to minimize CO2, SO2, and NOx pollution.

5 Conclusions

According to the results of this study, producing 1 kilogram of turmeric powder requires 7,963 MJ/kg of product, whereas producing chili powder requires 8,506 MJ/kg of product. The potential environmental implications of turmeric powder production are as follows: GWP of 0.7627 kg CO2 –eq, AP of 0.7796 x 10-4 kg SO2 –eq, and EP of 0.528 x 10-4 kg N –eq. The possible GWP released during the chili powder production process is 0.8418 kg CO2 –eq, the AP is 0.8690 x 10-4 kg SO2 –eq , and the EP is 0.664 x 10-4 kg N –eq.

The high value of GWP is due to the high value of CO2 emissions created during the raw material procurement process, hence advances in lowering CO2 in raw material procurement are required. One suggestion is to use full capacity delivery to reduce delivery frequency.

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