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Case study of life cycle assessment in bread production process

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Abstract. Technological advances sometimes bring negative effects, for example, there are emissions of gas and waste as a result of manufacturing activities. The research was carried out at the bread manufacturing with the intent calculate Life Cycle Inventory and Impact Assessment using life cycle analysis framework in ISO 14040. The stages of this research are from a preliminary study which contains goal definition and scope, followed by literature study, field survey and interview for data acquisition - inventory definition. The final stage is the analysis and conclusion that contains the impact analysis and interpretation of the impact. The impact measured up to the final process of bread making is the packaging stage using the 2002+ impact method. The results are there is the potential human health of 9.39E-05 DALY, ecosystem quality 42 PDF*m2*yr, climate change 118 kg CO2 eq and resources 247 MJ Primary. The comparison of baking, injection, and packaging process, it is found that there was a slight increase in damage category of human health and climate change, while no change in ecosystem quality. It is found in the study that the most dominant factor that contributes to environmental impact is the use of electricity.

Keywords: Impact 2002+, Life Cycle Assessment

I. Introduction

Nowadays, bread consumption is the part of the modern human lifestyle and it is predicted that there will be the growth of demand, for example in Indonesia. There is a slight shift in lifestyle and human diet, for example, the rise of flour base product consumption [1]. As the demand increase, it will give pressure to the environment. Several past environmental research about bread take place in several countries, for example about the production process of flat bread [2] and measurement of carbon footprint rye bread [3]. Study of life cycle assessment involves many parties in the discussion, not only academia but also the producer of several activities such as workshop [4]. The research is aimed to analyze the potential impact of damage assessment caused by bread production.



2. Methodology

The research takes place in one factory in Bandung and takes a kind of bread that frequently produced. Some type is produced manually in filling and packaging stage, while the rest using technology. In this study, the starting point is the mixing process until packaging that uses a semi-automatic packaging machine. The data such as the quantity of material and machining process are gathered by direct observation and interview on the production floor. Field observation which includes interview is very important at this stage, especially for inventory definition. Other data such as electricity can be found on the information paper on the machine. This research follows Life Cycle Assessment (LCA) framework ISO 14040 which become a common guideline for all the LCA research consists of goal definition, scope, life cycle inventory and life cycle impact assessment [5]. To complete the whole process from farm takes time and effort, and for early research, it is possible to borrow data provided by the database [6]. It will not give accuracy, as there are assumptions and uncertainties in LCA study such as the length of period bread stored that will come with another question about what kind of the storage, temperature and other variables [7].

3. Discussion

The study focus on the mass production of a variant of bread for the low-income market segment using the automatic filling machine. The manual operation is excluded from the research, due to none of the usage of energy involved. There are other types of bread and because of their similarity of the process, it is assumed that picking only a variant in this production floor is enough to represent another variant. The factory focuses only on their core business of bread making and leaves the rest supporting material such as plastic packaging and bread filling to the supplier to meet their need. Some key points in assumptions are:

1. Since the manufacturing process for variants that use the same automatic filling machine, data retrieval and calculation is for one flavour variant. It is assumed that the filling material can be neglected.
2. The functional unit is the calculation of LCA to 1 batch of production of a certain type of bread in company X using the automatic filling machine in 2017.
3. Due to data limitations, some of the data used comes from the ecoinvent 3.0 database
4. The LCIA method used is IMPACT 2002+ V2.12 / IMPACT 2002+

The main ingredients of bread that contribute greatly to the weight of bread products are wheat flour, sugar, eggs, shortening. Shortening is a fat that uses one of its basic ingredients is palm oil. The return product of bread will be returned to the factory, where there are two possibilities of bread that has expired or nearing its lifespan. They are collected by the factory and then sorted, for the expired ones will be sold to collectors which will purchase the items and then distribute to the fodder factory. Unexpired bread will usually be sold undervalue for limited time consumption.

4. Inventory Definition

The production process starts by first mixing the ingredients of wheat flour (x_1) and water (x_2) and stirred for 5 minutes. Next sequence is dough is removed from the mixer and kept for 10 minutes. The dough is re-inserted into the same mixer and on the second mixing process, the worker adds additional flour (x_3), egg (x_4), sugar (x_5), water (x_6) and shortening (x_7) so that accumulation of x_i will be:

$$\sum_{i=1}^7 x_i = 46 \text{ kg}$$

Where: $i \in N_1$

After that, the material is moved again and be kept for 10 minutes. Then the dough is cut into 5 big parts and put into a rolling machine that will put the ingredients into a solid tube and cut with an automatic machine. Next process is the material is moved into a plate that can contain 12 dough that has been cut into small pieces. Then the plate is stacked and stored in a storage room for 7 hours before baking. The oven capacity is 52 plate for each baking process, it means that the production rate per batch for 1250 pieces requires 2 times the roasting process. Roasting in the oven takes only 10 minutes and proceeds to remove the pan from the oven and the cooling down will take 1 hour. The work in process material then will be placed on the automatic filling machine and afterwards, the pan is transferred to the automatic packaging machine where the bread will run on the conveyor belt and then wrapped to be kept in the warehouse before being distributed to the consumer. Figure 1 describes the Sankey diagram for production process along with the energy and accumulation of mass for each stage.

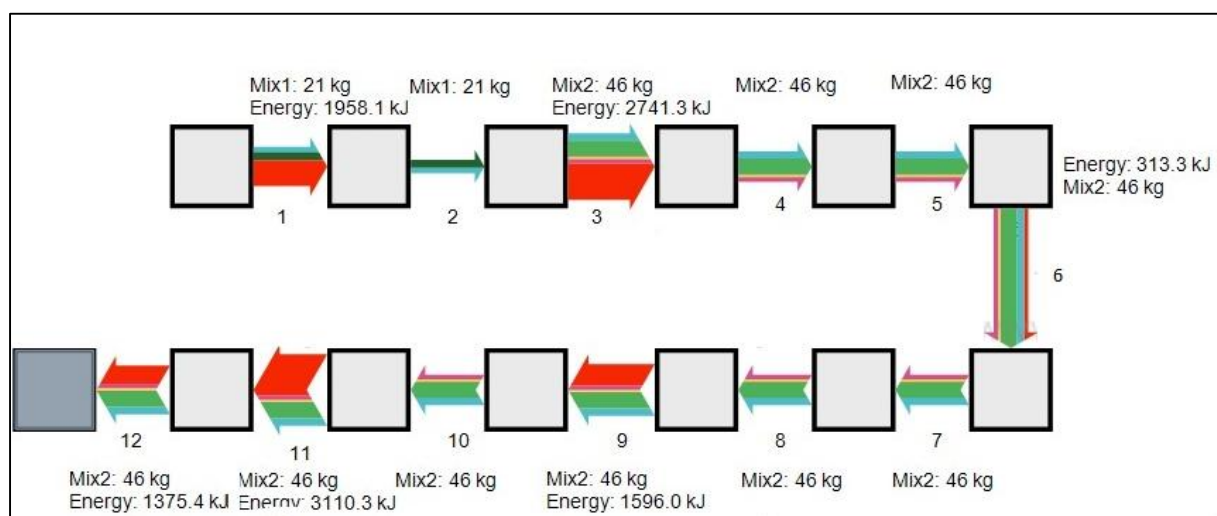


Figure 1. Sankey Diagram of Bread production

The total number of operations are 12 starting with mixing and end with packaging. The red arrow represents the electricity and another colour is ingredients added to that process. From the 12 stage of processes, half of them use electricity with the highest energy used is the process of injection of filling, caused by the time required to complete the whole batch. On the contrary, the lowest amount of electricity used in the process of rolling to slicing, it takes only 2.82% of the total energy used. The fact that it took approximately 2 minutes to feed all the 5 parts of dough in the slicing machine, result in the lowest energy consumption per kg. Table 1 illustrates the summary of operation, total mass flow and energy flow. It can be seen that only the first three process the material accumulated, after that the mass is steady. On process mixing 2 and injection, there are filling inserted, but it is excluded from the calculation. The unknown material on process 2 is the combination of several ingredients that mixed in the separate room while filling material on stage 11 is procured by the manufactured. It is liquid and sent in a plastic bin. The worker just puts them in the hopper on the filling machine.

Table 1. Operation, Material, Mass and Energy

Operation Number	Operation Name	Material Added	Total Mass Flow (kg)	Energy Flow (kJ)
1	Mixing 1	Flour, water	21	1958.1
2	Storing 1	-	21	-
3	Mixing 2	Flour, water, egg, shortening, sugar & unknown material	46	2741.3
4	Storing 2	-	46	-

5	Placing, Arrange, & Cutting	-	46	-
6	Tube forming, Run in conveyor & Slicing	-	46	313.3
7	Move to tray	-	46	-
8	Storing	-	46	-
9	Baking	-	46	1596.0
10	Cooling	-	46	-
11	Injection	Unknown material	46	3110.3
12	Packaging	-	46	1375.4

5. Impact Assessment & Interpretation

The amount of electricity used can be converted by the software to calculate CO₂ eq. Figure 2 describes the network diagram where electricity as the hotspot dominates the input of the technosphere in the production process. The diagram also shows the damage category of climate change which is 118 kg CO₂ eq. The Impact method 2002+ also gives the results of categories of damage to human health, ecosystem quality, and resources [8]. Table 2 as the output from the simapro software depicts the damage assessment to the stage of packaging, injection and baking and the result is not varied too much between each process, except for the category of resources and human health.

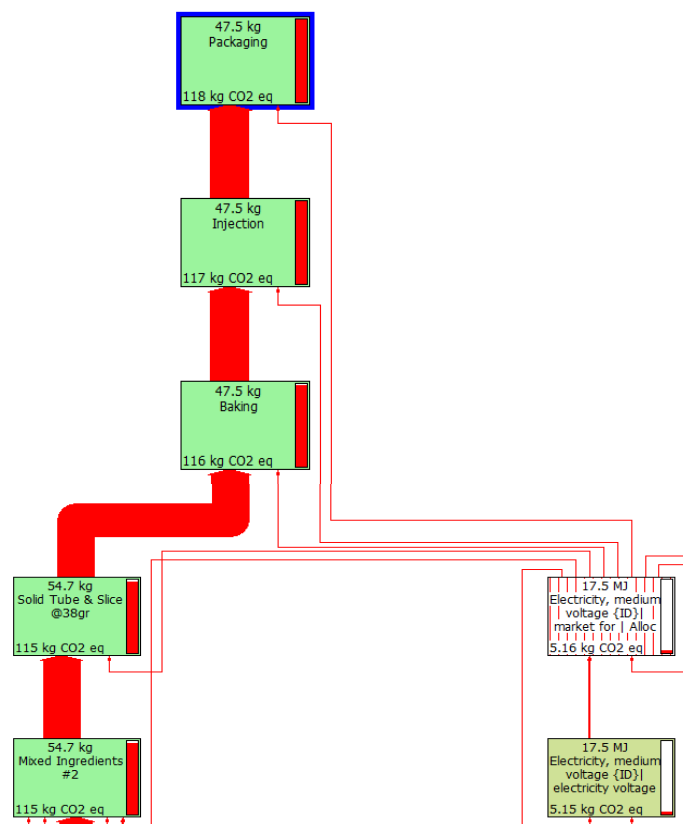


Figure 2. Network Diagram

The human health unit is measured in DALY (Disability Life Adjusted Years) which means a year lost due to a faster death or decreased quality of life in years due to illness. In this study, the result shows that a person reduced his age during $9.39\text{E-}05$ years. On the top of the list, electricity contribute 69.11% in this category.

The quality of the ecosystem is measured in PDF * m² * year (Potential Disappeared Fraction of Species) which means that the possible extinction of animals/plants is 42 species in 1 m² per year. From the network, the agriculture takes 26.99% to the total number in this damage assessment category.

Table 2. Damage Assessment Accumulation

Damage category	Unit	Packaging				Injection	Baking
		Ratio	Total	Significant Process Contributor	%	Total	Total
Human health	DALY	2.04E-6	9.39E-05	Electricity	69.11	8.8E-05	7.44E-05
Ecosystem quality	PDF*m ² *yr	0.92	42.6	Agriculture sector	26.99	42.6	42.5
Climate change	kg CO ₂ eq	2.56	118	Agriculture sector	73.55	117	116
Resources	MJ primary	6.02	277	Agriculture sector and lignite from the mining sector	45.41	272	259

Climate change is measured by the model undertaken by the IPCC (Intergovernmental Panel on Climate Change) with a unit of kg CO₂ eq which means Global Warming Potential which is generally calculated within 100 years. The biggest contributions are from agriculture which contributes to the 73.55% of climate change impacts. The ratio is calculated by dividing the value to the total production. It can be stated that for every kg production will result in 2.56 kg CO₂ eq. The total value for climate change is 118 kg CO₂ eq which is equivalent to the certain type of emissions [9]. The result is listed in table 3.

Table 3. Equivalence for 118 kg CO₂ eq

No	Type of Emission	Equivalence	Value
1	Greenhouse Gas Emission from	Miles driven by an average passenger vehicle	289.21
2	Greenhouse Gas Emission from	Passenger vehicles driven for one year	25.3
3	CO ₂ emissions from	Gallons of gasoline consumed	13.278

Depletion of Resources has several units such as MJ primary which means fossil fuel lost because it is used, in this research the figure is 277 MJ comes. The significant contribution comes from several parts, especially agriculture and mining sector which accumulate total 45.41%.

6. Conclusion

The functional unit is measured based on calculation per batch. Usually, it is measured in a unit, for example, one piece of bread and the information was put on the product label used as a marketing tool or campaign to educate the community about the environmental impact. However, the company can also use the batch-sized to measure the impact which is easier for them to calculate. The impact measured on the final process of bread making is the packaging stage using the 2002+ impact method resulting in the potential human health of $9.39\text{E-}05$ DALY, ecosystem quality 42.6 PDF * m² * yr, climate change 118 kg CO₂ eq and resources 277 MJ Primary.

For ecosystem quality, human health and climate change category there is no significant difference between the three processes. If compared each process of baking, injection and packaging, there is a slight increase in those processes. This is because there are no additional ingredients added to the last

three processes. Therefore for that kind of process, electricity contribute a significant amount to the impact category. To reduce the negative impacts of both people and the environment, manufacturers can start thinking of alternatives besides electricity such as using environmentally friendly energy such as using solar thermal power. It will benefit to future generation by providing long-term eco-friendly solutions to reduce the potential negative impact due to the use of resources or waste generated by the factory.

For further research can take place deeper in the chain of bakery industry such as distribution to retail or cradle like a chicken farm for the egg. Thus the database will be refined, to have a more complete and accurate data.

Acknowledge

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