Implementation of life cycle assessment on production of Fresh Pasteurized Milk

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Abstract. Cow fresh milk is managed and milked by dairy farmers then it is collected at Cooperation of Milk Farmers Warga Mulya. It is processed to pasteurized fresh milk and packed in plastic cup of 160 ml. Whole activities are influenced by scale of ownership, type of milking process and energy use for conducting activities. The objective of this research was to implement Life Cycle Assessment (LCA) on fresh pasteurized milk production. Some parameters were considered; milking technique and number of cows at every farmers. The LCA is a method to calculate the environmental impact of fresh pasteurized milk production. The samples were 10 farmer members. The process was started from milking at farmers, picking up the fresh milk, receiving milk at Cooperation, then milk processing or pasteurization. All energy, waste and others were collected, calculated, analyzed and then determined into environmental effect category. The results showed, that the energy use for carrying out all activities was reached by 3.8284 MJ/l. The highest emission was gained by pasteurization process released 47.3869 g/l CO₂ equivalent, 0.0564 g/l SO₂; 0.4823 g/l NOx and 0.0025 g/l CH₄. The highest impact to environment was contributed by pasteurization process as follow; Global Warming Potential (GWP) 87.6969 g CO₂ equivalent; Acidification Potential (AP) 1.6827 g SO₂ equivalent and Eutrophication Potential (EP) 0.7246 g NOₓ- equivalent.

1. Introduction

Based on National Statistic Agency production of fresh milk in Indonesia was very low, namely 847,086 ton per year (year 2012-2016). This amount fulfilled only 35% of national demand and the rest about 65% was covered by import fresh milk from Australia, New Zealand and European Union. Main dairy products imported to Indonesia were skim and whole milk powder, cheese, whey and butter (1). Due to Environment Impact Production (EIPRO) analysis, milk industry is one of food industries give significant contribution to environment. In 2006 it was stated, milk industry gave 5% of Global Warming Potential, 10% of Eutrophication Potential and 4% of ozone formation potential (2). Milk industry belonged to 10 biggest contributor to environment except ozone depletion. Effect of life cycle of eutrophication for dairy products was dominated by contribution of cow milk farm. It was divided into 10% of phosphor sources came from natural process of water, 7% from industry, 11% from detergent, 17% from agricultural fertilizers, 23% from human waste and the highest contributor 32% from farm waste (3).

In 2006 United Nations released the report of Livestock’s Long Shadow and in 2008 Kick the Habit. In both reports the farming industry gave contribution 18% of Green House Gases (GHG) consist of carbon dioxide (CO₂), methane (CH₄) and dinitro-oxide (N₂O), that was higher than contribution of
transportation mode in the world 13.5%. Furthermore the function change of the land into farm industry added 2.4 billion CO2 to the air every year. Use of land was disproportionately, 15 million km² for farming of foods and 30 million km² for livestock pastures (4).

These conditions led to environment effect, so that calculation and prediction of energy use, pollution, emission, waste that was released to environment were better executed. Life Cycle Assessment (LCA) is an environmental accounting and management approach that considers all the aspects of resource use and environmental releases associated with an industrial system from cradle to grave. LCA is a relative tool intended for comparison and not absolute evaluation, thereby helping decision makers compare all major environmental impacts when choosing between alternative courses of action (5).

The research was aimed to calculate and to evaluate energy use and environmental impacts of pasteurized fresh milk and packed in a plastic cup which was produced by Cooperation of Milk Farmers *Warga Mulya*, started from milking fresh milk, pasteurized fresh milk, then packed in a cup then distributed and sold to consumers. The waste, pollution and emission were also calculated for giving prediction value to be used as references for decision making. The results were predicted as potential hazards for global warming, eutrophication and acidification.

2. Methodology
This research was field research at Cooperation of Milk Farmers *Warga Mulya* and farmers who supplied fresh milk as raw material to the Cooperation. The product is pasteurized fresh milk and packed in 160 ml plastic cup with flavor of Vanilla, Melon, Strawberry, *Mocca* and Chocolate. The Observation was conducted from providing raw material, processing, until packing process. The samples were selected from ownership scale, number of cows and energy use.

The basic calculation for LCA used energy and mass balances from providing fresh milk to pack pasteurized milk. Some steps should be done for determining LCA, emission, and wastes, which were:
- a) defining goals and scoping LCA;
- b) Life Cycle Inventory;
- c) Impact analysis and assessment;
- d) Interpretation of results and giving recommendations for improvement.

The research was conducted by observation and survey on the location and followed all activities concerning fresh milk production. The Cooperation has 218 members and 675 cows, in which 283 in lactation phase, 70 dried cows and 322 young cows. The ownership was classified as follow; 89% small, 9% middle and 2% big farmers.

The all activities could be divided into:
- a. cow breeding (cow nurturing, feeding, cleaning and milking);
- b. delivering fresh milk to the Cooperation;
- c. Production unit (receiving fresh milk, milk test, pre-treatment);
- d. Pasteurization unit (pasteurization process, packing and selling).

The activities needed energy from electricity, fuel and human. During the process it was considered possibility of producing pollutants, waste and emissions which were calculated for determining environmental impacts.

3. Results and Discussion

3.1. Goal and Scoping
Goal and scoping of this research was to calculate and to evaluate the energy use and waste, pollutants and their environmental impacts. The scope or boundary of the study was all activities from farm to market of pasteurized milk, that was produced by Cooperation Warga Mulya, Cangkringan, Yogyakarta. The activities was started from farmer activities to look after and to milk the cows, then transported to Cooperation where the milk was tested for its quality performance, prepared to be sold in fresh condition and also as raw material for pasteurized milk, pasteurized in the equipment and added with flavoring agent before packed in 160 ml plastic cup, and then sold and delivered to consumers.

3.2. Life Cycle Inventory
Data collection was conducted by data inventory of all resources, energy use and emissions during all process that started from farmer to pasteurization unit. Human energy, electricity, fuel were energy
resources almost and all stages. The workers play still significant roles at farm, because they looked after and milked the cows. Then at transportation to cooperation normally the driver used motor cycle or three wheels motor cycle and he served also as lifter of milk container in farm and cooperation. Other energy sources came from fuel for motor cycle and generator, electricity for running devices at cooperation and lighting.

The flow of milk production was shown in the following figure 1:

![Flow of milk production](image1)

**Figure 1.** Flow of process from farm to market

Based on the results of energy use in three farmer groups, the smallest group consumed the highest energy especially on human energy, although all groups utilized almost the same amount of energy. But the milk production of smallest group was also lower than two other groups, so per functional unit the smallest group used more energy for conducting all activities in the farm. Overall the smallest one utilized the highest energy for electricity, human energy and fuel. The main cause was it has only less cows than other farmer groups, so the use of energy per liter fresh milk became higher or inefficient in term of energy use. Total energy use for all three groups was illustrated in table 1 as follow;

**Table 1.** Energy Use by Farmer Groups

| Energy Resources | Small Group | Middle Group | Big Group |
|------------------|-------------|--------------|-----------|
| Human (MJ/l)     | 1.216       | 0.217        | 0.549     |
| Fuel (MJ/l)      | 0.984       | 0.447        | 0.865     |
| Electricity (MJ/l)| 0.09       | 0.13         | 0.149     |
| Total            | **2.29**    | 0.794        | 1.563     |

When the energy use was compared in every stages of the production flow, the result showed that energy need was relatively high at processing stage. The average of farmer groups showed they were still lower than processing or pasteurization. In this stage more heat was utilized for making fresh milk safe to be consumed. The pasteurization played important role, because it had to be reduced or killed some pathogen microbes that were harmful for human health and Table 2 draws energy use for all stages of production.

**Table 2.** Energy Use for all production flow

| Energy Resources | Farmer group | Pick-up Milk | Cooperation | Pasteurization |
|------------------|--------------|--------------|-------------|----------------|
| Human (MJ/l)     | 0.661        | 0.006        | 0.004       | 0.064          |
| Fuel (MJ/l)      | 0.765        | 0.368        | 0           | 0.489          |
| Electricity (MJ/l)| 0.123       | 0            | 0.061       | 1.624          |
| Total            | **1.549**    | 0.0374       | 0.065       | 2.177          |

Based on table 2, the process for providing fresh milk at farmer level needed 1.549 MJ energy for 1 liter fresh milk. It was pick up by using motor cycle and one worker or driver then brought to cooperation. It needed only energy from fuel for motor cycle and human energy for taking milk. At the cooperation the activities were receiving fresh milk, pre-treatment such filtration and homogenization.
They used only energy from electricity and human. The 500 ml packed fresh milk was also sold at this place.

At pasteurization stage all energy was utilized, human energy was used for preparing and management the process. Energy from fuel and electricity were applied for the pasteurization process for achieving temperature at 70°C at for 3 minutes. The heat was significantly used in this stage, because it was critical point where fresh milk become “safe to be consumed” was applied. Pasteurization reduced also off-flavor in fresh milk and made it have longer shelf life. The energy use for producing 1 liter fresh pasteurized milk at Cooperation Warga Mulya, started from farm to ready to be delivered, was \(3.8284 \text{ MJ/liter}\)

### 3.3. Impact Analysis and Assessment

Calculation of emission was limited and focused on gases of \(\text{CH}_4, \text{CO}_2, \text{NO}_x\) and \(\text{SO}_2\) which were called greenhouse gases (GHG). Actually national database of GHG should be provided, but in some developing countries including Indonesia these data are not well documented and still in research reports. In this study international database of emission was applied for as reference for the calculation. In the farmer group level the emission was summarized as followed and shown in table 3.

#### Table 3. Emission at farmer group level

| Activities            | \(\text{CO}_2\) (g/l) | \(\text{SO}_2\) (g/l) | \(\text{NO}_x\) (g/l) | \(\text{CH}_4\) (g/l) |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Small farmer group    | 21.0333               | 0.0250                | 0.2491                | 0.0049                |
| Middle farmer group   | 18.2298               | 0.0217                | 0.1855                | 0.0015                |
| Big farmer group      | 22.5108               | 0.0268                | 0.2291                | 0.0028                |

At farmer level the big group produced highest value of emission for producing 1 l fresh milk. The emission was contributed mostly from fuel and \(\text{CO}_2\) became highest contributor. Furthermore the big farmer released more gases, which were from fuel, to the air and they needed energy 1.563 MJ/l or little above average (1.549 MJ/l). The small ones needed energy 2.71 MJ/l and contributed highest emission of \(\text{NO}_x\) and \(\text{CH}_4\) that probably were yielded from fuel.

#### Table 4. Emission at further processing steps (after farm level)

| Activities            | \(\text{CO}_2\) (g/l) | \(\text{SO}_2\) (g/l) | \(\text{NO}_x\) (g/l) | \(\text{CH}_4\) (g/l) |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Pick-up milk          | 18.1404               | 1.5999                | 0.0050                | 0.0037                |
| Cooperation           | 1.5793                | 0.0019                | 0.0161                | 0                     |
| Pasteurization Unit   | \textbf{47.3869}      | 0.0564                | \textbf{0.4823}       | 0.0025                |

Furthermore the highest emission of \(\text{CO}_2\) was achieved by pasteurization stage was 47.387 g/l, and emission of \(\text{NO}_x\) was 0.482 g/l. The highest value of \(\text{SO}_2\) emission was 0.7996 g/l and gained by pick-up the milk form farm to cooperation, and the highest \(\text{CH}_4\) emission was produced by small farmer group 0.0049 g/l. All emissions contributed to environmental effector impact assessment. Some environmental impacts were Global Warming Potential (GWP), Acidification Potential (AP) and Eutrophication Potential (EP).

#### 3.4. Interpretation of Results

#### Table 5. Classification on Environmental Effect of All Activities for Producing 1 liter Fresh Pasteurized Milk

| Effect / Emission | \(\text{CO}_2\) (g/l) | \(\text{SO}_2\) (g/l) | \(\text{NO}_x\) (g/l) | \(\text{CH}_4\) (g/l) |
|-------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Global Warming Potential | 87.6969      | -                     | -                     | 0.0093                |
Acidification Potential - 1.6827 0.7246 -
Eutrophication Potential - - 0.7246 -

Based on the result shown at table 5, the process of pasteurized milk at Cooperation Warga Mulya mostly contributed on Global Warming Potential, in which emission of CO\(_2\) and CH\(_4\) gave highest among other gases. The SO\(_2\) and NO\(_x\) gases influenced on Acidification, and NO\(_x\) gave effect on Eutrophication. It meant, the all activities should be managed and reduced energy use for producing same amount and quality level of this product. Although the pasteurization was as center of the process that needed more energy and produced more pollutant as well, other processes should be maintained and regularly controlled for increasing their efficiency and effectiveness.

4. Conclusion
The study on fresh pasteurized milk at Cooperation Warga Mulya concluded some points as follow;

a. The energy use for producing 1 l fresh pasteurized milk, started from farm level till ready to deliver was 3.8284 MJ. The energy came from human/worker, fuel for transportation and process and electricity for operating pasteurization equipment and lighting.
b. All level of processing steps contributed waste and pollutant, but mainly greenhouse gases emission released to the air. The CO\(_2\) emission dominated the pollutant for all processing steps and gave 87.6969 g CO\(_2\)-equivalent per 1 l milk production.
c. The environmental effect on this production mainly was Global Warming Potential, in which CO2 played most important role than other gases.

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