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Environmental Impact Evaluation of a Fresh Milk Production

Evaluasi Dampak Lingkungan Produksi Susu Segar

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Abstract

The study aimed to evaluate the waste impact on the environment in fresh milk production activities from the dairy cows rearing on farms to the distribution process of fresh milk to a milk processing factory and fresh milk selling agents, identify the most significant potential for contamination from fresh milk production activities on the environment, and provide alternative improvements based on the most significant environmental impact caused by fresh milk production activities. This research was conducted in a dairy farmer cooperative which is an organization that produces fresh milk. The Life Cycle Assessment (LCA) method was used to evaluate the environmental impact of fresh milk production activities. The analysis was carried out using SimaPro 9.0.0.47 software. The LCA stages carried out were Goal and Scope Definition, Life Cycle Inventory, Life Cycle Impact Assessment (LCIA), and Life Cycle Interpretation. The assessment of improvement alternatives was then analyzed using the pairwise comparison method to determine the highest weight. The results showed that the three most significant impact categories, namely eutrophication, human toxicity soil, and acidification. The biggest contamination from fresh milk production activities occurs in the fresh milk extraction process. Processing dairy cow dung into manure was the prioritized recommendation to reduce the impact.
Keywords: environmental impact, life cycle assessment, fresh milk

Abstrak

Penelitian ini bertujuan untuk mengevaluasi dampak limbah terhadap lingkungan pada aktivitas produksi susu segar mulai dari pemeliharaan sapi perah di peternakan sampai pada proses distribusi susu segar ke pabrik pengolah susu dan agen penjual susu segar, mengetahui potensi cemaran terbesar dari aktivitas produksi susu segar terhadap lingkungan, dan memberikan alternatif perbaikan berdasarkan dampak lingkungan terbesar yang disebabkan oleh aktivitas produksi susu segar. Penelitian ini dilakukan di a dairy farmer cooperative yang merupakan suatu organisasi yang memproduksi susu dalam bentuk segar. Metode Life Cycle Assessment (LCA) digunakan untuk mengevaluasi dampak lingkungan dari kegiatan produksi susu segar. Analisis dilakukan dengan software SimaPro 9.0.0.47. Tahapan LCA yang dilakukan adalah Goal and Scope Definition, Life Cycle Inventory, Life Cycle Impact Assessment (LCIA), dan Life Cycle Interpretation. Penilaian alternatif perbaikan kemudian dianalisis menggunakan metode perbandingan berpasangan untuk menentuan bobot tertinggi. Hasil penelitian menunjukkan bahwa tiga kategori dampak tertinggi yaitu eutrhopication, human toxicity soil dan acidification. Cemaran terbesar dari kegiatan produksi susu segar terjadi pada proses ekstraksi susu segar. Pengolahan kotoran sapi perah menjadi pupuk kandang merupakan rekomendasi yang diprioritaskan untuk mengurangi dampak tersebut..
Kata kunci: *dampak lingkungan, life cycle assessment, susu segar*

INTRODUCTION

Milk is one of the agroindustry product that has many health benefits due to its nutritional content. Milk contains many vitamins and minerals that are very good for the human body. Dairy cow's milk contains 4.80% lactose, 0.72% minerals, 3.90% fat, 3.40% protein, and 87.10% water (Soeparno, 2021). Fresh milk production in Indonesia has been done in some places. One of the greatest producer of fresh milk is in East Java. According to data from Statistics Indonesia, fresh milk production in East Java in 2020 was 534-151.52 tons (Badan Pusat Statistik, 2021).

All fresh milk production activities from farms to distribution of fresh milk to a milk processing factory and fresh milk selling agents generate waste, including dairy cow dung from dairy cows owned by farmers, air pollution due to fresh milk transportation activities from the fresh milk collecting post to the cooperative and from the cooperative to the factories and selling agents, liquid waste in the form of spilled fresh milk during transportation from the fresh milk collecting post to the cooperative, and many other possible wastes generated from these activities. Waste generated from fresh milk production activities in small and medium enterprises in Indonesia is still poorly handled, so it impacts the surrounding environment (Khalil et al., 2019). Environmental impact analysis is needed to reduce the impact of waste generated from fresh milk production activities on the environment.

Several studies on the agricultural industry by considering the industry's impact on the environment have been carried out previously. The research analysis focuses more on supply chain management (Mustaniroh, Kurniawan, & Deoranto, 2019; Lestari & Dinata, 2019) and productivity (Astuti, Deoranto, & Aula, 2019; Septifani, Astuti, & Akbar, 2020). The previous research does not consider the category of environmental impacts resulting from the industrial activities. Environmental impact categories are needed in determining alternative improvements based on the effect of emissions on the environment. Emissions result from all activities in the agricultural industry in various forms. These emissions must be converted into one unit, which is translated into one category of environmental impact so that it is easier to determine the alternative improvements to reduce these emissions.

The method used to assess the environmental impacts category in the product life cycle is Life Cycle Assessment (LCA). LCA is a method for evaluating the environmental impact of processes, products, and systems during their life cycle from start to finish by identifying and accounting for all associated inputs and outputs. The methodology in LCA is based on ISO 14040 (Ramos et al., 2021). Improvements can be made using LCA to create a sustainable production concept (Barzegar, Rasi, & Niknamfar, 2018).

This study aimed to evaluate the waste impact on the environment in fresh milk production activities, starting from the dairy cows rearing on farms to the distribution process of fresh milk to a milk processing factory and fresh milk selling agents, identify the most significant potential for contamination from fresh milk production activities on the environment, and provide alternative improvements based on the most significant environmental impact caused by fresh milk production activities. Alternative of improvements are then recommended to reduce the effects of waste generated by fresh milk production activities on the environment to create sustainable production.

METHODS

This research was conducted in a dairy farmer cooperative located in Mojokerto Regency, East Java. This dairy farmer cooperative collects fresh milk from farmers who are the members of the cooperative. The dairy farmer cooperative carries out the cooling process of fresh milk without the addition of other substances. The milk is then sold to a milk processing factory and fresh milk selling agents. The fresh milk extraction process involves 204 farmers who daily deliver fresh milk to the cooperative with an average volume of 5,667 liters.

Life Cycle Assessment (LCA)

LCA consists of four main stages, i.e. goal and scope, inventory analysis, impact assessment, and interpretation

Goal and Scope Definition

This stage was carried out to determine the goal and scope analyzed in this study. The purpose of the goal and scope definition was for evaluating the impact and determining the most significant potential for contamination due to the fresh milk production process. The goal and scope of this research was the activity of producing fresh milk from the dairy cows rearing on the farm to the distribution of fresh milk to a milk processing factory and fresh milk selling agents.

Life Cycle Inventory (LCI)

LCI data processing was performed after obtaining input and output data on all fresh milk production activities, starting from the dairy cows rearing on the farms to the distribution of fresh milk to a milk processing factory and fresh milk selling agents. The data was in the form of inputs and outputs on the extraction of fresh milk on farms, energy requirements in the production process, and transportation activities. The data at this stage was data for one month of the production process with the assumption that energy used did not change. The data was then processed using SimaPro 9.0.0.47 software. The method chosen in the software was Environmental Design of Industrial Product (EDIP) which was a characterization method for toxic substances produced in each process (Park et al., 2020). This method is most suitable for the conditions in the field in this study.

Life Cycle Impact Assessment (LCIA)

The LCIA stage was performed to compare the impact caused by each stage of the fresh milk production process. The outputs produced are network process, characterization, normalization, weighting, and a single score. The network process is an overall picture of the system studied. The contribution of each process contained in a system is identified in the network process. The most significant contribution can be seen from the red line in the network process (Palupi, Tama, & Sari, 2014). Characterization is an assessment of the value of substances that contribute to the impact category (Windrianto, Lucitasari, & Berlianty, 2016). Normalization is the stage of uniting the units for all impact categories. The purpose of normalization is to make it easier to compare between categories of impacts (Palupi et al., 2014).

Weighting was performed after normalization. Weighting provides an assessment of impact categories based on the importance level (Eranki & Landis, 2018). Single Score was then performed after weighting. Single Score provides an assessment of the most significant contribution at all stages of the production process. Single Score indicates the stage of the production process that has the most significant impact on the environment (Harjanto, Fahrurrozi, & Bendiyasa, 2012).

Life Cycle Interpretation

This stage includes drawing conclusions and recommendations related to the results of the LCI and LCIA. The interpretation results were several alternative improvements due to the most significant impact generated by fresh milk production activities. The weight value of the improvement alternatives was then calculated using pairwise comparisons to determine the recommended improvement alternatives priority.

Determination of Improvement Recommendations

Recommendations for improvement were based on the most significant impact of fresh milk production activities on the environment. The weighting on the improvement alternatives was then performed to determine the recommended improvement alternatives priority. The weighting was performed by expert respondents, i.e. a manager and a production head of the dairy farmer cooperative. The improvement recommendations' weight assessment was performed using pairwise comparisons with a rating scale of 1-9, as shown in Table 1. The assessment results were then processed using Super Decision software. The pairwise comparison matrix is declared consistent if the Consistency Ratio (CR) is $\leq$ 0.1 (Saaty, 2012a). The selected improvement recommendations are recommendations that have the highest weight (Saaty, 2012b).

RESULTS AND DISCUSSION

Goal and Scope Definition

The goal and scope of this research was the activity of producing fresh milk from the dairy cows rearing on farms to distribution to a milk processing factory and fresh milk selling agents. This included the extraction of fresh milk as the main raw material, the process of producing fresh milk, and the activities of transporting fresh milk from the milk collecting post to the cooperative and from the cooperative to the milk processing factory and fresh milk selling agents. Extraction of fresh milk is carried out on dairy cows owned by farmers who were the members of the dairy farmer cooperative. Dairy cows are fed grass, concentrate food, and water drinks. The average amount of grass needs is 50 kg/cow/day, the concentrate av

Table 1. Pairwise comparison rating scale

Interaction of Interests	Meaning/Interpretation
1	Both elements are equally important
3	One element is slightly more important than the other element
5	One element is more important than the other
7	One element is clearly more absolutely important than the other elements
9	One element is absolutely important than the other elements
2, 4, 6, 8	The values between two values of adjacent considerations

Source: Saaty (2012)

erage is 6 kg/cow/day, and the average water needed is 35 liters/cow/day for drinking and bathing. This livestock activity produces dairy cow dung with an average amount of 28 kg/cow/day. The total fresh milk produced every day is an average of 5,667 liters by 721 dairy cows, so that each dairy cow produced an average of 8 liters of milk/day

A dairy farmer cooperative carries out the fresh milk production process. The production process is only cooling fresh milk with a cooling machine without the addition of other substances. Cooling is done in order to make fresh milk remains in a good quality before being sent to a milk processing factory and fresh milk selling agents. The inputs to the production process in SimaPro 9.0.0.47 software in this study were fresh milk, electricity, and diesel fuel.

The fresh milk transportation activities considered in this study were transporting fresh milk from the milk collecting post to the cooperative and from the cooperative to the milk processing factory and fresh milk selling agents. The transportation activity uses a tank with a capacity of 1,000 liters for transportation activities from the milk collecting post to cooperatives and fresh milk selling agents. Transportation from the cooperative to the milk processing factory is carried out using a 6,000 liters capacity of a tank vehicle. The fuel used by tank is diesel fuel.

Life Cycle Inventory (LCI)

LCI is the stage of collecting data in the form of the number of inputs and outputs in the extraction of fresh milk as the main raw material, the process of producing fresh milk, and the activities of transporting fresh milk from the milk collecting post to the cooperative and from the cooperative to the milk processing factory and fresh milk selling agents. The input was the use of materials and energy in a process, while the output resulted from production or waste. The input and output data consisted of primary and secondary data and data available in the SimaPro 9.0.0.47 database.

Fresh milk was extracted from 721 dairy cows which require grass, concentrate, and water for their maintenance. Dairy cows also produce dung every day. Each number of inputs and outputs was multiplied by 721 which were the number of dairy cows as a source of fresh milk raw materials. The number of outputs and inputs for extracting fresh milk can be seen in Table 2.

The input data for the fresh milk production process were materials, i.e. fresh milk, water, and energy requirements in production (electricity and diesel fuel). Electricity is used as a source of energy in all activities, from lighting to the operation of cooling machines. Diesel fuel is used to fuel generators which function as a source of energy when the electricity goes out. The primary raw material input for fresh milk was obtained from the materials in the previous process (the extraction of fresh milk). Water is used for washing machines and milking equipment at the head office and other activities. The use of materials and energy in the fresh milk production process can be seen in Table 3.

Data conversion needs to be carried out on transportation activities to match the SimaPro 9.0.0.47 database because the units required in SimaPro 9.0.0.47 software in the transportation category are kilogram kilometers (kgkm). Conversion was performed by multiplying the load, and

Table 2. Number of outputs and inputs

Material	Database in SimaPro9.0.0.47	Unit	Quantity/day/head	Total/month
Grass	Grass, at dairy farm/NL Mass	kg	50	1,117,550
Water	Water, river, ID	liter	35	782,285
Concentrate	Compound feed dairy cattle/NL Mass	kg	6	134,106
Dairy cow manure	Manure, solid, cattle (waste treatment) {GLO}| market for | Conseq, U	kg	28	625,828

Table 3. Material and energy use per month

Material	Database	Unit	Total/month
Fresh milk	Fresh milk extraction	kg	180.075
Electricity	Electricity grid mix, AC, consumption mix, at consumer, 220V IS S	kWh	7.653
Diesel fuel	Diesel fuel, at refinery/l/US	liter	20
Water	Water, river, ID	liter	692.000

Table 4. Transport capacity and diesel fuel needed for fresh milk transport tanks

From or to the Cooperative	Distance (km)	Fresh Milk Quantity (kg)	Conversion (kgkm /day)	Conversion (kgkm /month)	Diesel Fuel / Day (liters)	Diesel Fuel / Month (liters)
Tank Capacity 1000 liters						
Milk Collecting Post A	3x2*	2,232	13,392	415,152	4	124
Milk Collecting Post B	4x2*	1,892	15,136	469,216	6	186
Milk Collecting Post C	15	660	9,900	306,900	10	310
Central Milk Collecting Post	0	1,025	0	0	0	0
Fresh Milk Selling Agents	30	658	19,740	611,940	30	930
Total			58,168	1,803,208	50	1,550
Tank Capacity 6000 liters						
Dairy processing factory	30	5,000	150,000	4,650,000	30	930

*Distance times the frequency of transportation in one day

the distance traveled from the milk collecting post to the cooperative and from the cooperative to the milk processing factory and fresh milk selling agents. Tank used in transportation activities have a capacity of 1,000 and 6,000 liters. The fuel used for the tank was diesel fuel, so diesel fuel was used as material in this transportation activity. The transport capacity from each fresh milk collecting post to the cooperative and from the cooperative to the milk processing factory and fresh milk selling agents can be seen in Table 4.

Life Cycle Impact Assessment (LCIA)

Network Process

Network Process is an overall picture of the system studied. The Network Process can identify the contribution of each process contained in a system. The most significant contribution can be seen from the red line in the network process (Palupi et al., 2014). Network Process of the fresh milk production activities in this study can be seen in Figure 1. The thickest line in the Network Process is in the fresh milk extraction process, so it can be concluded that the fresh milk extraction process provided the most significant contribution to the impact on the environment with a value of $1.37x10^3$ Pt. This result is caused by the process of extracting fresh milk impacts the environment in the form of solid waste of dairy cow dung which was directly discharged into the river without prior processing.

Characterization

Characterization is an assessment of the substantial value contributing to the impact category (Windrianto et al., 2016). The resulting impact category was based on the EDIP method on SimaPro 9.0.0.47 software. The characterization values for each impact category can be seen in Table 5 and Figure 2. The most significant impact categories in characterization were global warming (GWP 100) of $7.2x10^8$ g CO_2, photochemical smog of $6.13x10^4$ g of ethane, and eutrophication of $5.64x10^7$ g of NO_3.

Normalization

Normalization is the stage of uniformity units for all impact categories. The purpose of normalization is to make it easier to compare between categories of impacts (Palupi et al., 2014). Normalization values for each impact category can be seen in Table 6 and Figure 3. The most significant impact category in normalization was eutrophication, with a normalized value of 474. Eutrophication is water pollution caused by the enrichment of nutrient and mineral elements (such as nitrogen and phosphorus) which is causing an increase in biomass in the water's environment (Malone & Newton, 2020). Eutrophication was caused by dairy cow dung that was directly dumped into the river without prior processing.

Human toxicity soil was the second largest category of impacts caused by fresh milk production activities. Human toxicity soil affects human health through soil media. The normalized value for the impact category of human toxicity soil was 198. Excessive nutrition from livestock manure causes some nutrients to seep into the soil surface and eventually cause pollution. Phosphoric, phosphate, and nitric acids are some organic materials that affect soil contamination (Saputro, Wijaya, & Wijayanti, 2014).

The next most significant category impact caused by fresh milk production activities was acidification with a normalized value of 137. Acidification or acidity is caused by dairy cow dung waste in fresh milk extraction, which contains nitrogen. Nitrogen compounds are pollutants that have specific pollution effects and can have consequences for decreasing water quality due to the eutrophication process (Putri, Tama, & Yuniarti, 2014).

Weighting

Weighting is the stage of assessing the impact category based on the level of importance. The unit used for weighting is Pt or point. The Pt unit is a dimensionless value that is used as a measure of environmental indicators. A value of 1 Pt means one-thousandth of the environmental burden in 1 year on the average European population. The increase in the value of each impact category occurs in weighting because there is a direct weighting from the SimaPro 9.0.0.47 database (Eranki & Landis, 2018). The weighting values for each impact category can be seen in Table 7 and Figure 4. The highest impact categories from the weighting results were eutrophication, human toxicity soil, and acidification with the weight value of 0.569 kPt, 0.238 kPt, and 0.179 kPt respectively.

Single Score

Single Score is the stage of assessment of the most significant contribution to all processes. Single Score indicates the process that has the most significant impact on the environment (Harjanto et al., 2012). The single score assessment can be seen in Table 8 and Figure 5. The process that contributed the most significant impact was the fresh milk production process in the dairy farmer cooperative, with a total impact contribution of 0.719 kPt. This result was caused by the fresh milk extraction process as the input database of the fresh milk production process. The fresh milk extraction process contributed to the impact of 0.678 kPt. The impact contribution caused by the fresh milk production process itself was only 0.041 kPt, so that the fresh milk extraction process was still considered as the process that contributed the most significant impact at this Single Score stage.

The transportation process using a 1000-liter capacity tank generates the most significant impact after the impact contribution of fresh milk production process. The impact contribution generated by the transportation process was 0.0244 kPt. The smallest impact contribution was caused by the transportation process using a 6000-liters capacity tank which contributed 0.0147 kPt of impact. The distance load and diesel fuel needed for a tank with a capacity of 6000 liters were less than the distance load and diesel fuel needed for a tank with a capacity of 1000 liters so so the impact contribution of the 6000-liters capacity tank was also smaller. According to Jeong et al. (2018), the pollution factors associated with emissions are generated mainly by diesel-fueled engines.

Life Cycle Interpretation

This stage includes a conclusion and recommendations related to the results of the LCI and LCIA. The interpretation results were several alternative recommendations for improvement on the most significant impact generated by the fresh milk production process activities. The recommended alternative improvements were processing dairy cow dung into biogas, processing dairy cow dung into manure, and utilizing dairy cow dung into bricks. The alternative recommendations for improvement were obtained based on literature studies and discussions with expert respondents.

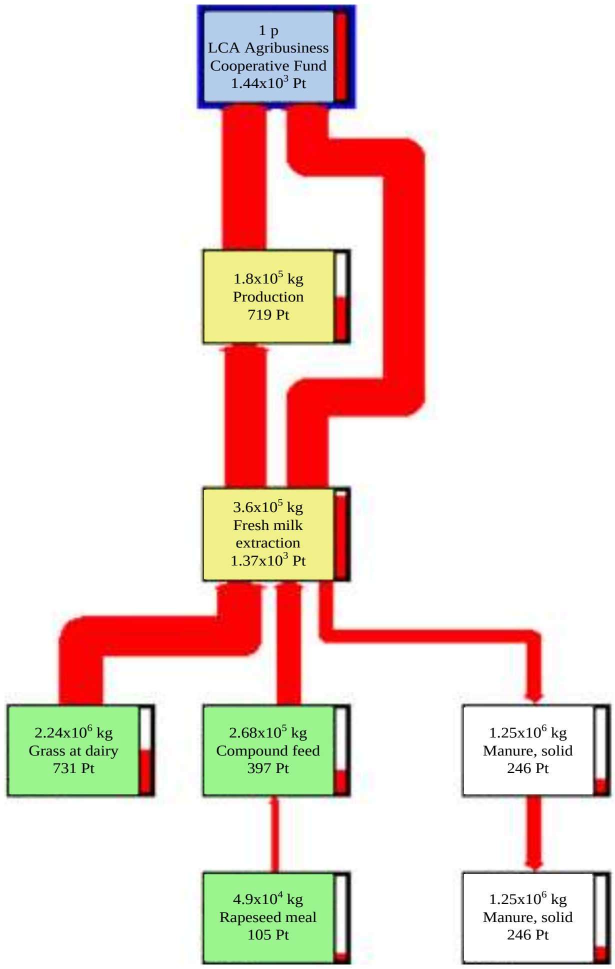

Figure 1. Network Process

Table 5. Table of characterization values

Impact Category	Unit	Total	Production	Fresh Milk Extraction	Transportation of 1000 liter Capacity Tank	Transportation of 6000 liter Capacity Tank
Global warming (GWP 100)	g CO_2	$7.2x10^8$	$3.59x10^8$	$3.59x10^8$	$7.43x10^5$	$4.46x10^5$
Ozone depletion	g CFC-11	8.65	4.33	4.33	0.000178	0.000107
Acidification	g SO_2	$1.02x10^7$	$5.09x10^6$	$5.07x10^6$	$9.31x10^3$	$5.58x10^3$
Eutrophication	g NO_3	$5.64x10^7$	$2.82x10^7$	$2.82x10^7$	$6.18x10^3$	$3.71x10^3$
Photochemical smog	g ethene	$6.13x10^4$	$2.92x10^4$	$2.92x10^4$	$1.87x10^3$	$1.12x10^3$
Ecotoxicity water chronic	m^3	$3.42x10^7$	$1.46x10^7$	$1.46x10^7$	$3.14x10^6$	$1.88x10^6$
Ecotoxicity water acute	m^3	$2.65x10^6$	$1.08x10^6$	$1.07x10^6$	$3.14x10^5$	$1.88x10^5$
Ecotoxicity soil chronic	m^3	$1.04x10^7$	$5.22x10^6$	$5.22x10^6$	104	62.6
Human toxicity air	m^3	$4.19x10^{10}$	$2.67x10^{10}$	$1.49x10^{10}$	$1.54x10^8$	$9.25x10^7$
Human toxicity water	m^3	$4.02x10^6$	$2x10^6$	$2x10^6$	$6.97x10^3$	$4.18x10^3$
Human toxicity soil	m^3	$2.52x10^4$	$1.39x10^4$	$1.11x10^4$	132	79
Bulk waste	kg	796	402	394	x	x
Hazardous waste	kg	0.762	0.381	0.381	x	x
Radioactive waste	kg	0.397	0.198	0.198	x	x
Slags/ashes	kg	$1.08x10^3$	542	542	x	x
Resources (all)	kg	4.43	2.18	2.15	0.0615	0.0369

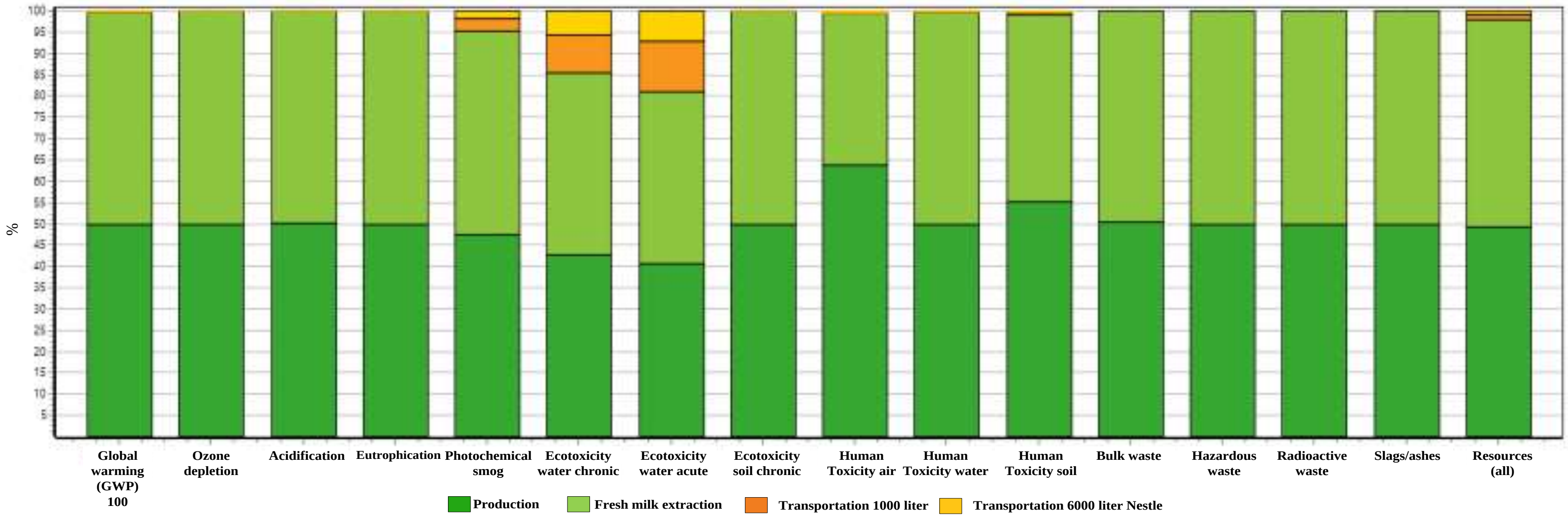

Figure 2. Graph of Characterization Value

Table 6. Table of normalization values

Impact Category	Unit	Total	Production	Fresh Milk Extraction	Transportation of 1000 liter Capacity Tank	Transportation of 6000 liter Capacity Tank
Global warming (GWP 100)		82.8	41.3	41.3	0.0855	0.0513
Ozone depletion		0.084	0.042	0.042	$1.72x10^{-6}$	$1.03x10^{-6}$
Acidification		137	68.7	68.5	0.126	0.0754
Eutrophication		474	237	237	0.0519	0.0312
Photochemical smog		2.45	1.17	1.17	0.075	0.045
Ecotoxicity water chronic		97.2	41.5	41.4	8.91	5.34
Ecotoxicity water acute		91.2	37	36.9	10.8	6.47
Ecotoxicity soil chronic		10.9	5.43	5.43	0.000108	$6.51x10^{-5}$
Human toxicity air		13.7	8.74	4.88	0.0504	0.0302
Human toxicity water		77.1	38.5	38.5	0.134	0.0802
Human toxicity soil		198	109	87.4	1.04	0.621
Bulk waste		0.59	0.298	0.292	x	x
Hazardous waste		0.0368	0.0184	0.0184	x	x
Radioactive waste		11.3	5.67	5.67	x	x
Slags/ashes		3.1	1.55	1.55	x	x
Resources (all)		x	x	x	x	x

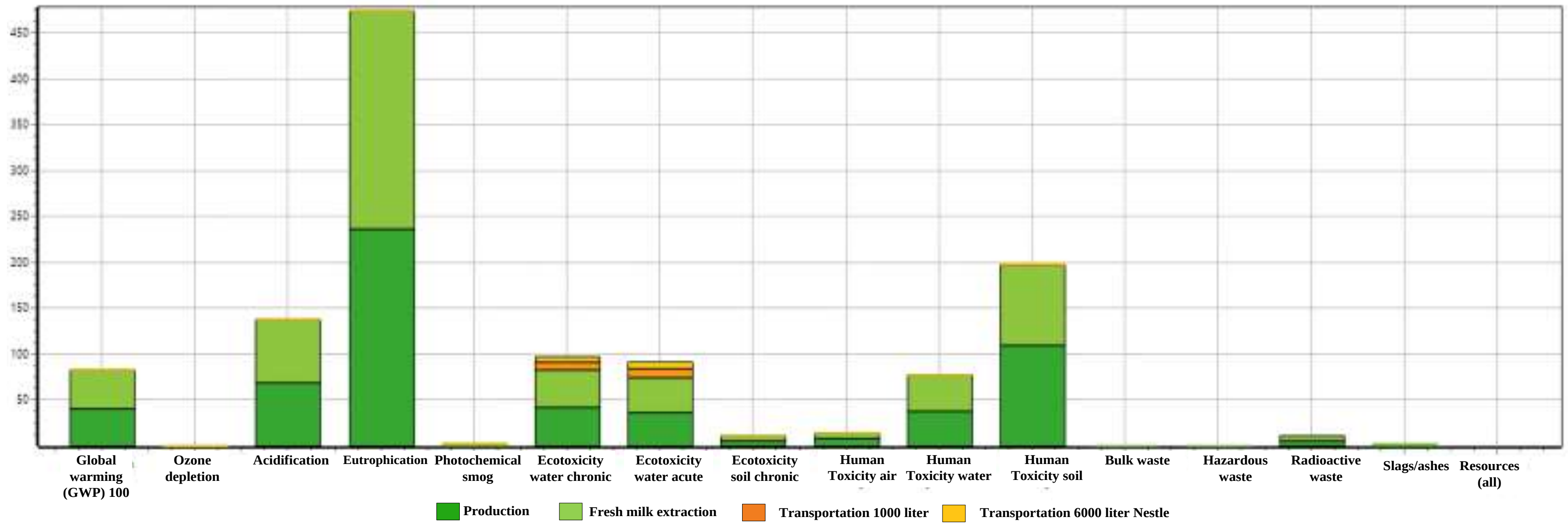

Figure 3. Graph of Normalization Value

Table 7. Table of weighting values

Impact Category	Unit	Total	Production	Fresh Milk Extraction	Transportation of 1000 liter Capacity Tank	Transportation of 6000 liter Capacity Tank
Total	kPt	1.44	0.719	0.687	0.0244	0.0147
Global warming (GWP 100)	kPt	0.0911	0.0455	0.0454	$9.4x10^{-5}$	$5.64x10^{-5}$
Ozone depletion	kPt	0.00529	0.00265	0.00265	$1.09x10^{-7}$	$6.52x10^{-8}$
Acidification	kPt	0.179	0.0894	0.089	0.000163	$9.8x10^{-5}$
Eutrophication	kPt	0.569	0.284	0.284	$6.23x10^{-5}$	$3.74x10^{-5}$
Photochemical smog	kPt	0.00319	0.00152	0.00152	$9.74x10^{-5}$	$5.85x10^{-5}$
Ecotoxicity water chronic	kPt	0.117	0.0499	0.0497	0.0107	0.00641
Ecotoxicity water acute	kPt	0.1	0.0407	0.0406	0.0119	0.00712
Ecotoxicity soil chronic	kPt	0.0109	0.00543	0.00543	$1.08x10^{-7}$	$6.51x10^{-8}$
Human toxicity air	kPt	0.0151	0.00961	0.00536	$5.54x10^{-5}$	$3.33x10^{-5}$
Human toxicity water	kPt	0.1	0.05	0.05	0.000174	0.000104
Human toxicity soil	kPt	0.238	0.131	0.105	0.00124	0.000746
Bulk waste	kPt	0.000649	0.000328	0.000321	x	x
Hazardous waste	kPt	$4.05x10^{-5}$	$2.03x10^{-5}$	$2.03x10^{-5}$	x	x
Radioactive waste	kPt	0.0125	0.00624	0.00624	x	x
Slags/ashes	kPt	0.00341	0.00171	0.00171	x	x
Resources (all)	kPt	x	x	x	x	x

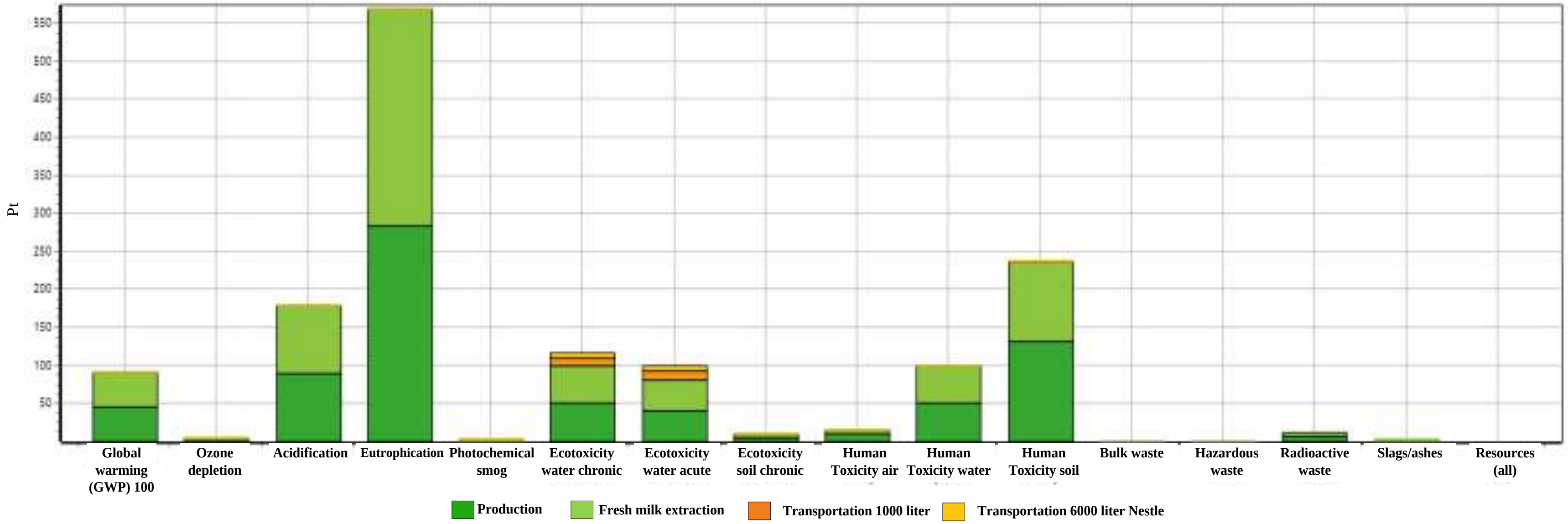

Figure 4. Graph of Weighting Valu

Tabel 8. Table of single score values

Impact Category	Unit	Total	Production	Fresh Milk Extraction	Transportation of 1000 liter Capacity Tank	Transportation of 6000 liter Capacity Tank
Total	kPt	1.44	0.719	0.687	0.0244	0.0147
Global warming (GWP 100)	kPt	0.0911	0.0455	0.0454	$9.4x10^{-5}$	$5.64x10^{-5}$
Ozone depletion	kPt	0.00529	0.00265	0.00265	$1.09x10^{-7}$	$6.52x10^{-8}$
Acidification	kPt	0.179	0.0894	0.089	0.000163	$9.8x10^{-5}$
Eutrophication	kPt	0.569	0.284	0.284	$6.23x10^{-5}$	$3.74x10^{-5}$
Photochemical smog	kPt	0.00319	0.00152	0.00152	$9.74x10^{-5}$	$5.85x10^{-5}$
Ecotoxicity water chronic	kPt	0.117	0.0499	0.0497	0.0107	0.00641
Ecotoxicity water acute	kPt	0.1	0.0407	0.0406	0.0119	0.00712
Ecotoxicity soil chronic	kPt	0.0109	0.00543	0.00543	$1.08x10^{-7}$	$6.51x10^{-8}$
Human toxicity air	kPt	0.0151	0.00961	0.00536	$5.54x10^{-5}$	$3.33x10^{-5}$
Human toxicity water	kPt	0.1	0.05	0.05	0.000174	0.000104
Human toxicity soil	kPt	0.238	0.131	0.105	0.00124	0.000746
Bulk waste	kPt	0.000649	0.000328	0.000321	x	x
Hazardous waste	kPt	$4.05x10^{-5}$	$2.03x10^{-5}$	$2.03x10^{-5}$	x	x
Radioactive waste	kPt	0.0125	0.00624	0.00624	x	x
Slags/ashes	kPt	0.00341	0.00171	0.00171	x	x
Resources (all)	kPt	x	x	x	x	x

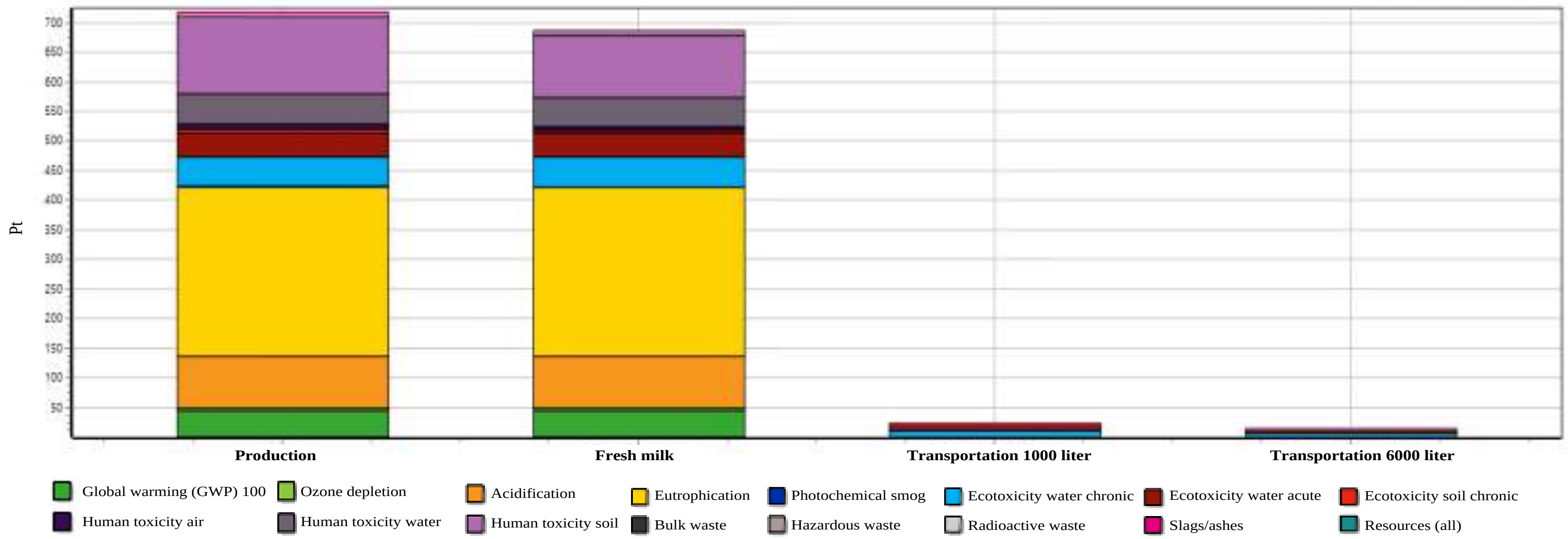

Figure 5. Graph of Single Score

Alternative Selection

LCA results showed that the most significant impact of all fresh milk production activities in dairy farmer cooperatives was the process of extracting fresh milk. The recommended alternative improvements were processing dairy cow dung into biogas, processing dairy cow dung into manure, and processing dairy cow dung into bricks. The recommended alternative improvements had also been successfully implemented in Bangladesh to reduce emissions produced by cow dung (Rahman et al., 2017). Biogas is a renewable energy source that can be used to replace fossil fuel energy sources. The decomposition of organic material produces biogas by microorganisms. Biogas is more environmentally friendly than fuel oil because biogas is made from renewable materials (Wahyuni, 2013).

Another alternative improvement to reduce the impact of fresh milk production activities on the environment was processing dairy cow dung waste into manure. Livestock waste is the result of the livestock business. The waste can be processed into compost, which can increase crop production, increase environmental carrying capacity, increase farmers' income, and reduce environmental pollution (Okoroafor et al., 2013).

Processing dairy cow dung into bricks was also recommended to reduce the impact of fresh milk production activities on the environment. Bricks from dairy cow dung are the same as bricks in general, with the primary raw material being a mixture of clay and dairy cow dung. Bricks from dairy cow dung have an absorption value of 6% so that the bricks are included in the B bricks category (Nugroho & Annur, 2014).

The weight assessment of the improvement recommendations was then performed using pairwise comparisons to determine the recommended improvement alternatives priority. The assessment results were then processed using Super Decision software. The analysis results showed that the alternative improvement with the highest weight was the processing of dairy cow dung into manure with a weight value of 2,425. The weight value for processing dairy cow dung into biogas was 0.587, while the weight value for processing dairy cow dung into bricks was 0.212. Consistency measurements were then performed to determine the consistency of expert respondents in conducting pairwise comparison assessments. The measurement was carried out by calculating the Consistency Ratio (CR) value in Super Decision software. The CR calculation results showed that the CR value was 0.07. This value means that expert respondents were consistent in conducting pairwise comparison assessments, and the results can be used as a basis for decision-making.

CONCLUSIONS

The results showed that the impacts categories resulting from fresh milk production activities in the dairy farmer cooperative were global warming (GWP 100), ozone depletion, acidification, eutrophication, photochemical smog, ecotoxicity water chronic, ecotoxicity water acute, ecotoxicity soil chronic, human toxicity air, human toxicity water, human toxicity soil, bulk waste, hazardous waste, radioactive waste, slags/ashes, and resources (all). The highest impact categories from these activities were eutrophication, human toxicity soil, and acidification. The most significant contamination potential from fresh milk production activities occurred in the fresh milk extraction process with an impact value of 1.37×10^3 Pt. Alternative priorities for improvement to reduce this impact were processing dairy cow dung into manure, processing dairy cow dung into biogas, and processing dairy cow dung into bricks with weight values of 2.425, 0.587, 0.212, respectively. Further research can evaluate the impact resulting from the dairy products production activities in the milk processing factory.

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