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EVALUATION OF FRESH MILK USING LIFE CYCLE ASSESSMENT (LCA) AND ANALYTICAL HIERARCHY PROCESS (AHP) FOR IMPLEMENTATION OF GREEN SUPPLY CHAIN MANAGEMENT

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ABSTRAK

Penelitian ini bertujuan untuk mengkaji bagaimana limbah dari pembuatan susu segar mempengaruhi lingkungan. Kegiatan rantai pasok susu segar dimulai dari kegiatan peternakan sapi perah hingga proses distribusi susu segar hingga industri pengolahan susu segar. Penelitian ini dilakukan di koperasi peternakan sapi perah perusahaan pembuat susu segar yaitu Koperasi Produsen Karya Nugraha Jaya Kuningan. Proses pembuatan susu segar dievaluasi dampaknya terhadap lingkungan menggunakan pendekatan *Life Cycle Assessment* (LCA). SimaPro 9.5 digunakan untuk melakukan analisis. Berdasarkan hasil LCA diketahui bahwa kegiatan ekstraksi susu segar yang terjadi di peternakan mempunyai kontribusi dampak paling tinggi sebesar 3.57E3 Pt. Usulan perbaikan diberikan berdasarkan kegiatan ekstraksi susu segar dengan pendekatan Analytical Hierarchy Process. Metode perbandingan berpasangan digunakan untuk menilai alternatif perbaikan yang disarankan dan memastikan mana yang mempunyai bobot terbesar. Instalasi Pengolahan Air Limbah (IPAL) direkomendasikan sebagai perbaikan yang diprioritaskan dengan nilai total sebesar 0,48963.

Kata kunci: supply chain, life cycle assessment, AHP, green supply chain management.

ABSTRACT

The purpose of this study is to assess how waste from the manufacturing of fresh milk affects the environment. Activities in the fresh milk supply chain begin with dairy farming and continue through the fresh milk distribution process and the fresh milk processing sector. This study was carried out in a dairy farming cooperative, a company that makes fresh milk, namely Karya Nugraha Jaya Producer Cooperative Kuningan. The fresh milk manufacturing process is evaluated for its utilizing the Life Cycle Assessment (LCA) method to assess environmental effect. SimaPro 9.5 was used to conduct the analysis. Based on the results of the LCA, it is known that the fresh milk extraction activities that occur on the farm have the highest impact contribution of 3.57E3 Pt. Proposed improvements are given based on fresh milk extraction activities using the Analytical Hierarchy Process approach. The pairwise comparison method was employed to assess the suggested improvement alternatives and ascertain which one had the largest weight. The Installation of Wastewater Treatment (IPAL) was recommended as a prioritized improvement with a total value of 0.48963.

Keywords: supply chain, life cycle assessment, AHP, green supply chain management.

INTRODUCTION

The growth of the industrial sector in the current era of globalization is growing rapidly accompanied by increased demand for goods and services in meeting the needs of life (Silalahi, U. C., Gozan, M., & Chairani, E., 2021). According to data from the Central Statistics Agency (BPS) in 2020, 16.27 kg of milk was consumed annually per capita on average in Indonesia. This figure is still far from Malaysia with a consumption rate of 26.20 kg/capita/year, Myanmar at 26.7 kg/capita/year, and Thailand at 22.2 kg/capita/year (Putra, 2022). Meanwhile, milk processing in Indonesia also increases every year as a result of population expansion, increased public income, and of milk consumption. A good production process not only pays attention to aspects of efficiency and effectiveness, but environmental aspects in the form of safety and side effects of waste must also be considered. The existence of the dairy industry raises the issue of environmental pollution.

The dairy industry is one of the food sectors that contributes the most to the volume of liquid waste pollution due to its large water consumption (Rohmanna, N. A., Azizah, N., & Hidayat, N., 2021). Effects on the environment occur throughout the product life cycle, starting from procuring basic materials, manufacturing processes, use, product recycling to the disposal stage. The dairy industry contributes 5% to the potential for global warming, 10% to the potential for eutrophication, and 4% to the possibility of creating ozone by photochemical means. Through the exception of ozone depletion, the liquid dairy sector is among the top 10 overall environmental impactors. The primary source of life cycle eutrophication impacts for all dairy products is dairy production (Cahyaputri, B., YaniM., & SugiartoS., 2021).

Green supply chain management is an extension of the traditional supply chain with a series of activities that aim to reduce the influence on the environment of the entire product life cycle (Susanty, A., Santosa, H., & Tania, F., 2017). Green Supply Chain Management is an approach by utilizing a combination of environmental concepts into a supply chain strategy that is used to overcome problems related to aspects of waste that arise due to a production system that uses various materials such as chemicals, solid waste and liquid waste. The Green Supply Chain Management method can be used in evaluating the environmental performance of companies involved in the supply chain strategy (Singh, E. B., Singh, E. N. N., & Sinha, D. P., 2017). This method is among the crucial tactics in achieving sustainable development for the company (Puryono, D. A., Mustafid, & Jie, F., 2016).

Life cycle assessment (LCA) is one method for evaluating the environmental issues associated with the entire industrial process. The life cycle assessment (LCA) process assesses the product's inputs, outputs, and any effects on the environment based on the principles and framework of ISO 14040 (2016), which is a document about life cycle analysis and environmental management (BSN, 2016). In accordance with the aforementioned description, research was conducted at the Karya Nugraha Jaya Producer Cooperative with the objective of assessing the environmental performance of supply chain activities. It is therefore necessary to adopt an effective approach to calculating environmental impacts. Accordingly, the authors must conduct research on the evaluation of environmental impacts on dairy supply chain activities with the Life Cycle Assessment (LCA) approach. This will make it possible to analyze the influence on the environment of the dairy milk supply chain.

METHODS

The research method is the work steps of the researcher in conducting research. This study employed descriptive research using a quantitative methodology and a qualitative approach. The quantitative approach is in the form of alternatives resulting from data processing using the Life Cycle Assessment method which is weighted in the Analytical Hierarchy Process component. The data needed in this research are primary data and secondary data.

The following is a flowchart on this research.

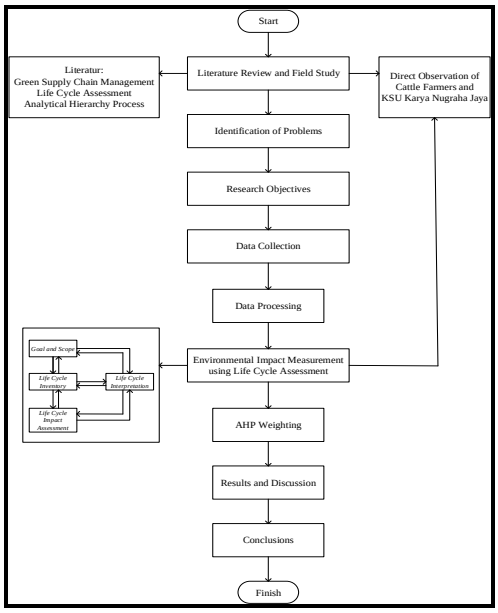

Figure 1. Research Flowchart (Data Processing)

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Measurement of environmental impact in one life cycle of dairy milk products was conducted using the Life Cycle Assessment method, then identifying Life Cycle Inventory to calculate the input and output of the life cycle stages in the supply chain network using SimaPro 9.5 to get the impact assessment value where there are three elements that will be obtained, namely characterization, normalization, and weighting. The following are the stages of measuring environmental impacts with the Life Cycle Assessment method.

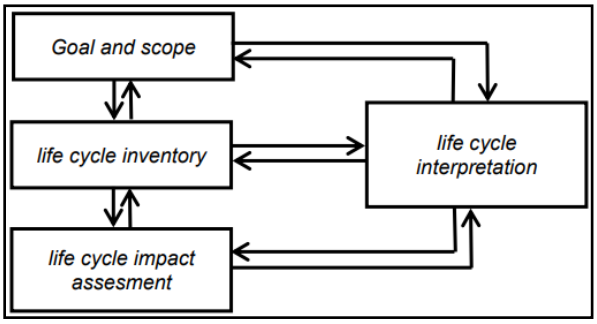

Figure 2. Stages of Environmental Impact Measurement (Data Processing)

The LCA method is carried out for impact calculations based on the LCA implementation guidelines according to the ISO 14040 Framework (2006) which divided into four phases, namely:

1. Goal and Scope Definition

This phase involves identifying the goals and constraints of the study. This assessment's scope is cradle to gate since the research was constrained, allowing for an analysis that began at dairy farms and continued until fresh milk was ready for processing. The scope of cradle to gate discusses the use and disposal of products (Dr. Elanda Fikri, 2021).This stage determines the unit function that will be used in the research, namely 1 kg of fresh milk as a reference for normalization of inputs and outputs. Inputs consist of raw materials, supporting materials, water, and energy that enter the process. Outputs consist of products, air emissions, emissions to water, and soil.

2. Life Cycle Inventory

At this point, the components, resources, and emissions released into the atmosphere during the course of the fresh milk life cycle are broken down. The data used is derived from two sources: secondary data, such as data, and primary data, such as field observations and interviews on energy requirements, water, raw materials, waste generated, and publications from previous research results.

3. Life Cycle Impact Assessment

At this stage, the impact on the environment obtained from the results of the step of the Life Cycle Inventory is determined. After that, the calculation of environmental impact is carried out using SimaPro 9.5. The method used in this data processing is Environmental Design of Industrial Products (EDIP).

4. Life Cycle Interpretation

Interpretation of results is an evaluation and analysis of the results of the environmental impact analysis of fresh milk supply chain activities, then determine and make solutions to improve or reduce negative impacts that can be implemented effectively and efficiently to improve environmental performance.

Furthermore, the qualitative data analysis method is carried out by conducting interviews with resource persons. The method used is data processing with a quantitative approach, namely the Analytical Hierarchy Process to address environmental hotspots in identifying and evaluating various alternative solutions that have the potential to reduce the environmental influence of the fresh milk extraction stage based on the Life Cycle Assessment output. AHP is a method that takes into account several subjective factors such as perception, preference, experience and intuition (Malik, A. Y., & Haryanti, T., 2018).

Data processing is done with the help of Super Decisions software. The use of Super Decisions is easier and more efficient in operation, and has been equipped with various features to analyze the output results (Darmawan, 2018). The next step is to fill in the pairwise comparison table for each element in the hierarchy in order to assess the level of preference which is the level of importance between elements in the hierarchy based on the assessment of respondents.

Table 1. Pairwise Comparative Evaluation System

Interaction of Interests	Meaning/Interpretation
1	The two components are of equal significance
3	One component is marginally more significant than the other
5	One component holds greater significance than the other
7	One component is more crucial than the others
9	One component is unquestionably more significant than the others
2, 4, 6, 8	The values between two values of adjacent considerations

Source: Saaty (2012)

RESULT AND DISCUSSION

Analysis of the Life Cycle Assessment method on the life cycle of cow's milk at Karya Nugraha Cooperative has four stages of the process to determine the effect of supply chain activities. The stages to start Life Cycle Assessment are determining goals and scope, examining and interpreting life cycle assessments and inventories.

Goal and Scope of Life Cycle Assessment (LCA)

The goal and scope of this research is to determine and analyze the life cycle of cow's milk products from supply chain activities at Karya Nugraha Jaya Cooperative starting from raising cows on the farm to distributing fresh milk to the Milk Processing Industry (IPS) or milk retailers and MSMEs selling fresh milk. The scope of pure milk production is the provision of feed, activities on the farm, milk transportation activities from farmers to Milk Collection Points (TPS), transportation from TPS to Karya Nugraha Jaya Cooperative, then transportation from the cooperative to the Milk Processing Industry (IPS).

Life Cycle Inventory (LCI)

Primary, secondary, and data from the SimaPro 9.5 database make up the input and output data. At this point, the data is based on a single month's worth of production, assuming that energy consumption stays constant. The data is processed using software, namely SimaPro 9.5 The method used in processing this data is Environmental Design of Industrial Products (EDIP) which is a method of characterizing toxic substances produced from each process (Park, W.-J., Kim, R., Roh, S., & Ban, H., 2020).

Fresh milk extraction is carried out by farmers who join as farmer groups in Karya Nugraha Jaya Cooperative. Based on the results of the accountability report of Karya Nugraha Jaya Producer Cooperative in Kuningan in 2022, the total production of fresh milk in the cooperative resulted in an average milk production of 23,644.15 liters per day by 1,885 dairy cows. Each cow produces an average of 12.5 liters of milk per day. Considering the findings of the interviews with cattle farmers in Karya Nugraha Jaya Producer Cooperative Kuningan, the amount of forage needs is an average of 40 kg/head/day of grass, an average concentrate of 9 kg/head/day, straw is 6 kg/head/day, silage is 6 kg/head/day, tofu pulp is 15 kg/head/day, ground cassava is 1.25 kg/head/day, and the average water requirement is 35 liters/head/day. Cattle farming activities

produce an average of 30 kg/head/day of animal manure. Cattle feeding at Karya Nugraha Jaya Cooperative cattle farm is done in the morning and evening. The following is a table of inventory data on livestock activities.

Table 2. Farm *Inventory* Data (Data Processing)

Materials	Unit	Total
Input		
Concentrate	kg	508950
Grass	kg	1131000
Straw	kg	339300
Silage	kg	339300
Tofu Dregs	kg	848250
Ground Cassava	kg	70687,5
Feed and Drinking Water	L	2262000
Maintenance Water	L	8482500
Electricity	kWh	1695,6
Milkcan washing water	L	19030
Output		
Fresh Milk	kg	709342,5
Waste Water	L	8501530
Animal Feces	kg	1696500

The following is a pie chart diagram as a visualization based on the inventory input data table above to show the proportion of each input category.

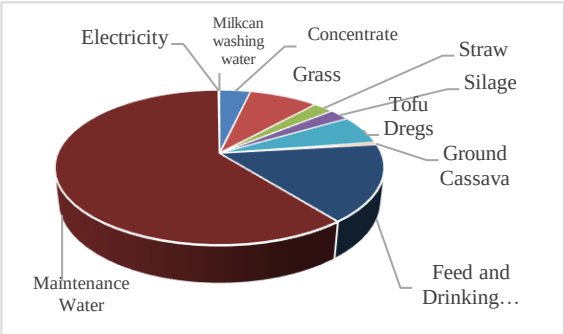

Figure 3. Pie Chart of Inventory Data (Data Processing)

Before fresh milk is distributed to the Milk Processing Industry (IPS), milk cooling is carried out first at the Milk Cooling Unit (MCU) owned by the Karya Nugraha Jaya Kuningan Producer Cooperative. Data input for cooperative activities, specifically the cooling process used in the manufacturing of fresh milk from raw materials like water and fresh milk, as well as the energy needed for production in the form of electricity. Table 4.2 Inventory Data on Material and Energy Usage shows how materials and energy are used during the manufacturing of fresh milk.

Table 3. Inventory Data of Material and Energy Usage (Data Processing)

Materials	Unit	Total
Input		
Fresh Milk	kg	709342,5
Electricity	kWh	1920
Washing Water	l	4500
Output		
Fresh Milk	kg	709342,5
Waste Water	L	4500

Furthermore, fresh milk is distributed by the cooperative to the Milk Processing Industry using diesel-fueled tank trucks.

Life Cycle Impact Assessmemt (LCIA)

Life Cycle Impact Assessment (LCIA) is a stage to analyses the environmental impacts resulting from each process. This phase compares the effects that are brought about by every step in the manufacture of fresh milk. All data that has been obtained both primary and secondary data and data that has been calculated and converted at the stage of Life Cycle Inventory (LCI) results in an impact assessment value, then the analysis's conclusions based on the largest impact category will be the basis for improvement in this study. The method used in analysing is Environmental Design of Industrial Products (EDIP). The output of this stage is Network Process, Characterization, Normalization, Weighting, and Single Score.

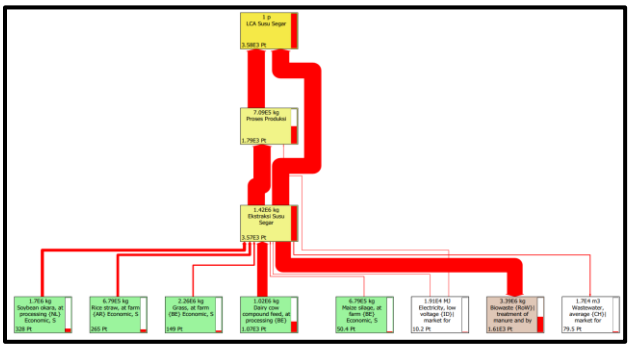

Figure 2. *Network Process Life Cycle Assessment* (Data Processing)

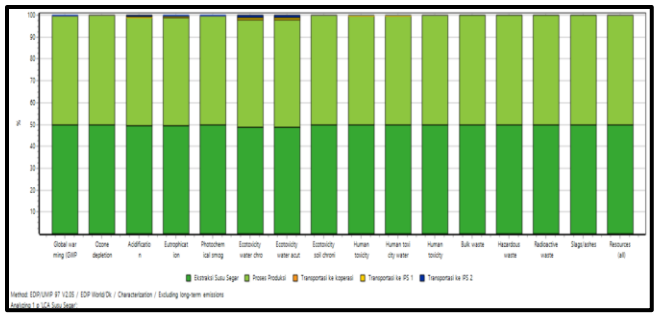

Figure 3. *Characterization* (Data Processing)

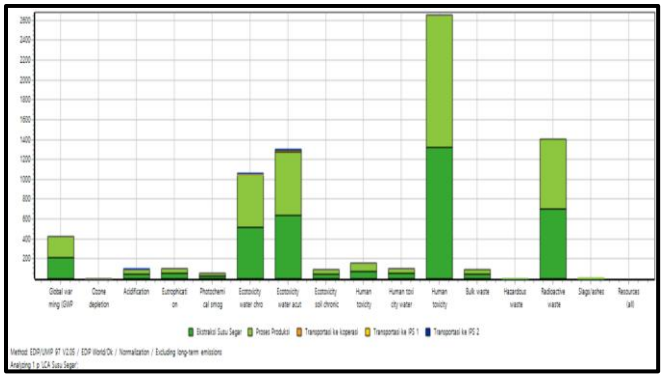

Figure 4. *Normalization* (Data Processing)

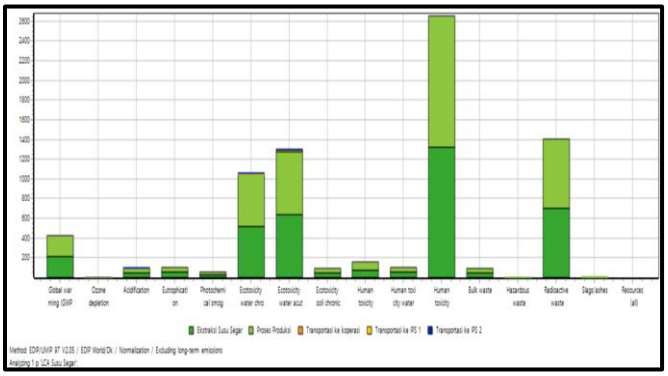

Figure 5. *Weighting* (Data Processing)

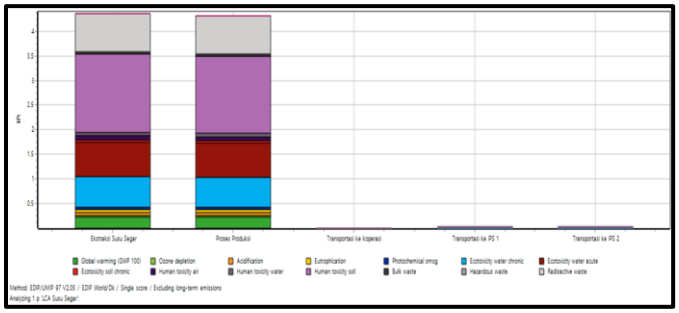

Figure 6. *Single Score* (Data Processing)

Interpretation of the results of the evaluation of impact of each process unit of fresh milk life cycle activities aims to determine the highest impact and make improvement efforts. The results of the fresh milk life cycle analysis show the environmental impact of various stages and activities in the product life cycle is 8.8 kPt. The life cycle analysis's findings that fresh milk extraction activities are environmental hotspots that need to be the main focus of improvement.

This shows that the fresh milk extraction stage contributes significantly to the total environmental effect of fresh milk during the product life cycle. Improvements to fresh milk

extraction activities aimed at improving the environmental performance of fresh milk focus on extraction and production efficiency, adopting more sustainable agricultural technologies and practices, and optimizing the use of resources such as energy and water.

As a result of brainstorming with cooperative management, several alternative improvements were proposed to reduce the environmental impact of fresh milk extraction activities. The proposed alternatives are solar panels, wastewater treatment plants (WWTP), and biogas processing. All three alternatives have the potential to make a significant contribution in creating an environmentally friendly and sustainable supply chain. Hierarchical preparation is based on determining the objectives or goals of this AHP method, namely the selection of alternative proposed improvements for putting green supply chain management into practice in the fresh milk life cycle with the criteria of cost, environmental impact, and social impact. There are sub criteria for each criterion with a total of seven sub criteria and three alternatives, namely biogas, WWTP, and solar panels. The following is the output of AHP processing using Super Decisions software.

Graphic	Alternatives	Total	Normal	Ideal	Ranking
	Biogas	0.0464	0.1393	0.2846	3
	IPAL	0.1632	0.4896	1.0000	1
	Panel Surya	0.1237	0.3710	0.7578	2

Figure 7. Alternatives Ranking (Data Processing)

Based on the output of alternative ranking, it can help decision making in planning Green Supply Chain Management implementation improvement proposals in the fresh milk life cycle by considering cost criteria, environmental impacts, and social impacts in creating a more sustainable supply chain. The selected alternative is the Wastewater Treatment Plant (WWTP) for proposed improvements to fresh milk extraction activities on dairy farms.

CONCLUSION

The results of the study explain the effects of activities related to fresh milk production starting from farm activities, activities in the cooperative to the IPS receiving fresh milk distribution. The categories where these activities have the greatest effects include soil human toxicity, acidification, and eutrophication. The fresh milk extraction procedure has the highest risk potential contamination resulting from the manufacturing of fresh milk, with an effect value

of 3.57E3 Pt. An alternative priority for improvement aimed at reducing this impact is wastewater treatment in the form of a selected The Installation of Wastewater Treatment (IPAL) with a value of 0.4896. Additional investigation is needed to assess the effects of dairy production operations in milk processing facilities. To extend the scope of this research in a methodical and comprehensive manner, future research ought to concentrate on the subsequent stages of milk processing within the WWTP framework. This will facilitate a more holistic understanding of the environmental impacts across the entire dairy production lifecycle. This would entail a comprehensive assessment of the impact mitigation efficiencies of WWTP implementations, evaluating not only their operational effectiveness but also their integration with existing dairy production processes. An investigation of these aspects could provide a more nuanced understanding of the environmental footprint of dairy products, thereby informing more targeted improvements in the industry's sustainability practices.

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