Life Cycle Assessment (LCA) For Preparation Of Environmental Impact Reduction Proposal On Cheddar Cheese Production Process

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ABSTRACT

While beneficial for businesses, the increasing number of food industries each year also poses environmental challenges such as global warming and ozone depletion. One such developing industry is Jogja Cheese House (KEJUGJA), which produces various types of cheese. The energy consumption in each production process adversely affects the environment, and improper disposal of whey waste, a by-product of cheese production, adds to the problem. This study aims to assess the environmental performance of the production process and propose improvement strategies. The research focuses on cheddar cheese production. The method used is Life Cycle Assessment (LCA), which involves four main stages: goal and scope definition, inventory analysis, impact assessment, and interpretation. The goal and scope define the research objectives, focusing on energy, water, and fuel use in cheddar cheese production. Inventory analysis is conducted using the gate-to-gate method to measure mass and energy use. Impact assessment identifies emissions and their environmental contributions. Based on LCA results, a fishbone diagram is used to identify problems from six aspects: people, methods, machines, materials, environment, and leadership. The proposed improvements from the fishbone diagram include conducting training sessions by environmental agencies and NGOs, establishing long-term contracts with milk suppliers to ensure quality standards, using Material Requirement Planning (MRP) to manage raw material demand fluctuations, considering High-Temperature Short-Time (HTST) pasteurization, and processing whey waste into value-added products like whey protein, whey-based drinks, and whey crackers, or using it as an additive in cow feed.

Keywords: Life Cycle Assessment, cheddar cheese, environmental impact, waste management

1. INTRODUCTION

Public interest in cheese has significantly increased the demand for cheese products in Indonesia. In 2022, national cheese demand rose by 12.5%, and this percentage is expected to grow annually, given cheese's vital role as a food ingredient in today's culinary world. The rising demand for cheese has encouraged the expansion of the cheese processing industry, from micro to macro-scale enterprises, which have become increasingly prevalent in society. One such enterprise is UMKM Rumah Keju Jogja (KEJUGJA), a micro, small, and medium enterprise (MSME) located in Sleman Regency, Special Region of Yogyakarta. KEJUGJA specializes in processing fresh cow's milk into various types of natural cheese, including cheddar cheese. KEJUGJA processes 110 liters of cow's milk daily to produce cheddar cheese. The cheese production process generates a by-product known as whey, a liquid waste with relatively high nutritional content. Cheese whey comprises 95.1% water, 0.85% protein, 0.27% fat, and 4.7% lactose. Despite its potential for reuse, whey that is not managed correctly can lead to environmental pollution. At KEJUGJA, the current practice involves disposing of whey waste into nearby infiltration sources. This practice has resulted in environmental pollution, particularly during the dry season, causing a foul odor and the darkening of water bodies. Additionally, KEJUGJA's production process involves the excessive use of electrical energy, contributing to carbon emissions. For example, a 2200 W cheese vat is used for cheese pasteurization to separate the whey for 8 hours. In addition to this, two 1 PK air conditioners (AC), two 196 W ice boxes, two 115 W refrigerators, and one 190 W showcase unit are used continuously for 24 hours to maintain cheese refrigeration, further increasing energy consumption and environmental impact. Given these issues, this study addresses the problem of proposing improvements to the cheese production process at KEJUGJA UMKM to mitigate the most significant negative environmental impacts. This research aims to develop strategies that optimize the cheese production process at KEJUGJA, focusing on reducing whey waste pollution and excessive energy consumption, thereby promoting a more sustainable and environmentally friendly production approach.

2. LITERATURE REVIEW

Widyastuti (2010) defines cheese as a processed milk product made from cow, goat, sheep, or other mammal milk. It involves removing water through rennet and fermentation, resulting in a nutritious product commonly used in various processed foods. Hilman & Kristiningrum (2008) stated that the International Organization for Standardization, commonly called ISO, established by the International Organization for Standardization in 1947, focuses on creating international standards for environmental management. It benefits organizations by improving environmental practices across different sectors, including goods, services, and government. According to Irawati & Andrian (2018), Life Cycle Assessment (LCA) is is a method for evaluating the environmental impacts of a product throughout its entire life cycle, from material extraction to disposal. LCA helps improve process efficiency, reduce costs, and support green marketing. According to Santoso & Ronald (2012), OpenLCA developed by GreenDelta2 in 2006, is software that facilitates LCA and sustainability assessments. It simplifies the analysis of environmental impacts using various databases. According to Mustafa (2015), mass balance is based on the conservation of mass principle, which states that the mass entering a system equals the mass leaving it. It is used to evaluate material flow and composition within a system. According to Agustina (2021), the energy is grounded in the law of energy conservation, which asserts that energy cannot be created or destroyed. It provides insights into energy production, transformation, and usage within a system. According to the Big Indonesian Dictionary (KBBI), energy consumption refers to the use of energy for various processes. Electrical energy, in particular, is derived from mechanical or chemical interactions and is used to power human activities through various forms such as motion and light. The fishbone diagram, as described by Gaspersz (2001), is a key quality tool used to identify the causes of a problem by emphasizing cause-and-effect relationships. It helps teams identify and address the root causes of issues, aiding in problem-solving, generating ideas, and formulating actions for improvement.

Previous studies on ecological impact using Life Cycle Assessment (LCA) typically focus on different aspects depending on the approach. This study will employ LCA methods, including ReCiPe Endpoint (H) V1.13 and CML 2 Baseline 2000 V2.05, to assess the environmental impacts of cheese production at UMKM Rumah Keju Jogja (KEJUGJA) using a gate-to-gate system. Following the LCA analysis, a fishbone diagram will be created to address the identified impacts and manage whey waste, based on methods outlined by Khasanah, Faishal, and Suharyanto (2021).

3. METHOD

Data processing in this study involves handling primary and secondary data to address the identified issues. The inventory analysis phase includes data collection on all stages of the cheese production process, such as pasteurization, acidification, coagulation, curd cutting, cheese heat treatment, whey separation, cheese salting, molding, packaging, and energy use. Mass and energy balances are calculated, including electrical energy usage for refrigeration and cheese VAT operations and fuel calculations for LPG. The goal and scope of the Life Cycle Assessment (LCA) are defined to analyze the environmental impact of cheddar cheese production at UMKM KEJUGJA using a gate-to-gate approach. Life Cycle Inventory (LCI) quantifies inputs and outputs in the production process using primary and secondary data from KEJUGJA and literature. Data collection involves direct observation, interviews, and process flow diagram creation to show input needs and emissions. Life Cycle Impact Assessment (LCIA) evaluates environmental impacts using CML IA Baseline and Recipe Endpoint methods, focusing on categories such as human health, ecosystems, and resources. This includes characterization, normalization, weighting, and single-score calculations to compare processes. Interpretation combines LCI and LCIA results using OpenLCA software to identify significant environmental impacts and determine the least impactful improvement options. A fishbone diagram is developed based on LCA results to identify root causes of significant environmental impacts, categorized using the 4M+1L framework (methods, machines, materials, people, environment), which helps formulate proposals for improvements to the cheddar cheese production process. The data processing process for this study can be seen in Figure 1.

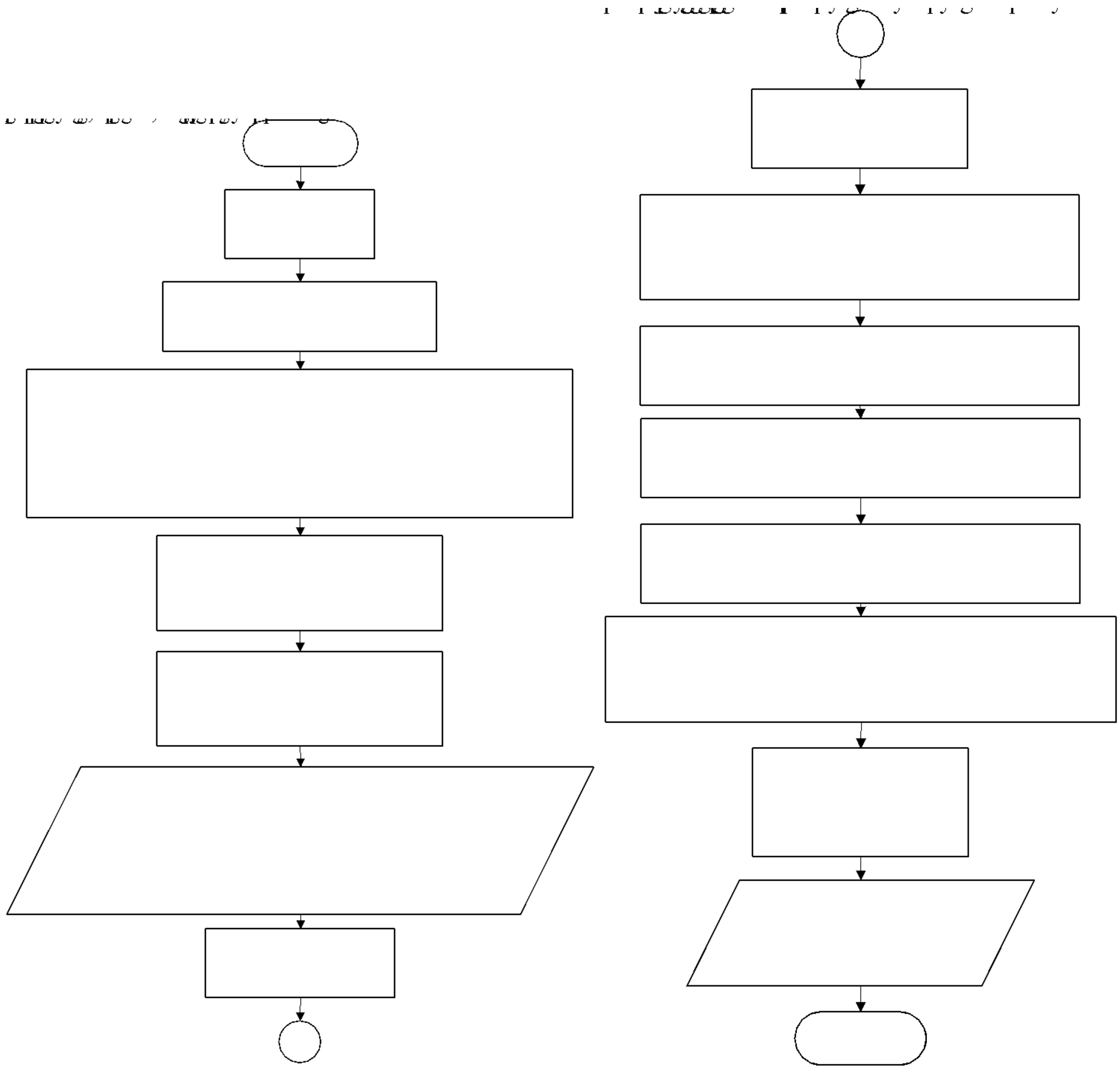

Figure 1. Data processing

4. RESULTS AND DISCUSSION

At the impact assessment stage, the environmental impacts were determined from the Life Cycle Inventory (LCI) stage using the CML IA Baseline method. At the characterization stage, it was found that the milk pasteurization process contributed the most significant impact with a total value of 3968.62 for the milk pasteurization process, with the three most significant environmental impacts being marine aquatic ecotoxicity with a value of 3212.08 kg 1.4DB-eq, abiotic depletion (fossil fuels) with a value of 635.28 MJ, and global warming (GWP100a) with a value of 117.27 kg CO2-eq. The following is a graph of the characterization analysis of the cheese production process, which can be seen in Figure 2. The characterization analysis value can be seen in Figure 3.

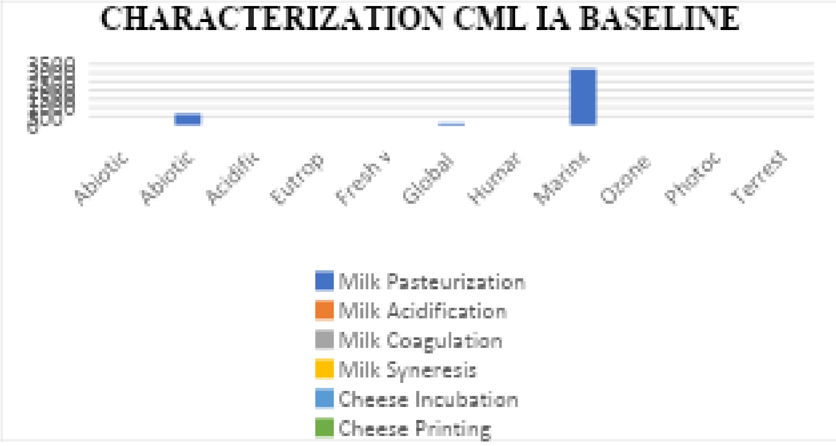

Figure 2. Analysis graph of the characterization of the cheese production process using the CML IA Baseline method

Impact Indicators	Milk Pasteurization	Milk Acidification	Milk Coagulation	Milk Syneresis	Cheese Incubation	Cheese Printing	Cheese Packaging
Abiotic depletion	3,01858E-06	0	0	0	0	0	0
Abiotic depletion (fossil fuels)	635,2807404	0	0	0	0	0	0
Acidification	0,768093379	0	0	0	0	0	0
Eutrophication	0,165865483	0	0	0	0	0	0
Fresh water aquatic ecotox.	0,928943881	0	0	0	0	0	0
Global warming (GWP100a)	117,2678776	0,000610214	0,000254243	0,000533287	5,7175E-05	0,001245896	1,29943E-05
Human toxicity	2,094059526	0	0	0	0	0	0
Marine aquatic ecotoxicity	3212,079842	0	0	0	0	0	0
Ozone layer depletion (ODP)	8,34319E-06	0	0	0	0	0	0
Photochemical oxidation	0,02674663	0	0	0	0	0	0
Terrestrial ecotoxicity	0,012187853	0	0	0	0	0	0

Figure 3 Characterization analysis values using the CML IA Baseline method

Then, at the normalization stage, through normalization analysis, it was found that the pasteurization process has the most significant impact with a total value of 0.0000000000273097, with the three most significant environmental impacts being marine aquatic ecotoxicity with a value of 0.0000000000165743 kg 1.4DB-eq. There is acidification with a value of 0.00000000000321831 kg So2 eq and global warming (GWP100a) with a value of 0.0000000000028027 kg CO2-eq. The following is a graph of the normalization analysis of the cheese production process, which can be seen in Figure 4. The normalization analysis value can be seen in Figure 5.

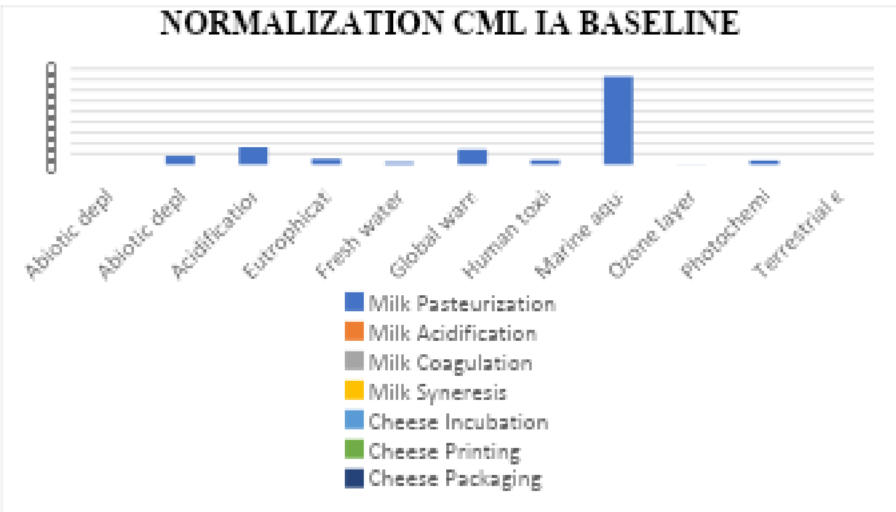

Figure 4. Analysis graph of the normalization of the cheese production process using the CML IA Baseline method

Impact Indicators	Milk Pasteurization	Milk Acidification	Milk Coagulation	Milk Syneresis	Cheese Incubation	Cheese Printing	Cheese Packaging
Abiotic depletion	1,44288E-14	0	0	0	0	0	0
Abiotic depletion (fossil fuels)	1,67079E-12	0	0	0	0	0	0
Acidification	3,21831E-12	0	0	0	0	0	0
Eutrophication	1,04827E-12	0	0	0	0	0	0
Fresh water aquatic ecotox.	3,92943E-13	0	0	0	0	0	0
Global warming (GWP100a)	2,8027E-12	1,45841E-17	6,07641E-18	1,27456E-17	1,36648E-18	2,97769E-17	3,10564E-19
Human toxicity	8,12495E-13	0	0	0	0	0	0
Marine aquatic ecotoxicity	1,65743E-11	0	0	0	0	0	0
Ozone layer depletion (ODP)	3,67935E-14	0	0	0	0	0	0
Photochemical oxidation	7,27508E-13	0	0	0	0	0	0
Terrestrial ecotoxicity	1,11519E-14	0	0	0	0	0	0

Figure 5. Normalization analysis values using the CML IA Baseline method

At the impact assessment stage, the environmental impact obtained from the Life Cycle Inventory (LCI) stage was determined using the Recipe 2016 Endpoint (H) method. It began with the characterization stage. Based on the results of the characterization that had been carried out, it was found that the milk pasteurization process contributed the most significant impact, with a total value of $ 6.68, with the most significant environmental impact being the scarcity of fossil resources. The following is a graph of the characterization analysis of the cheese production process, which can be seen in Figure 6. The characterization analysis value can be seen in Figure 7.

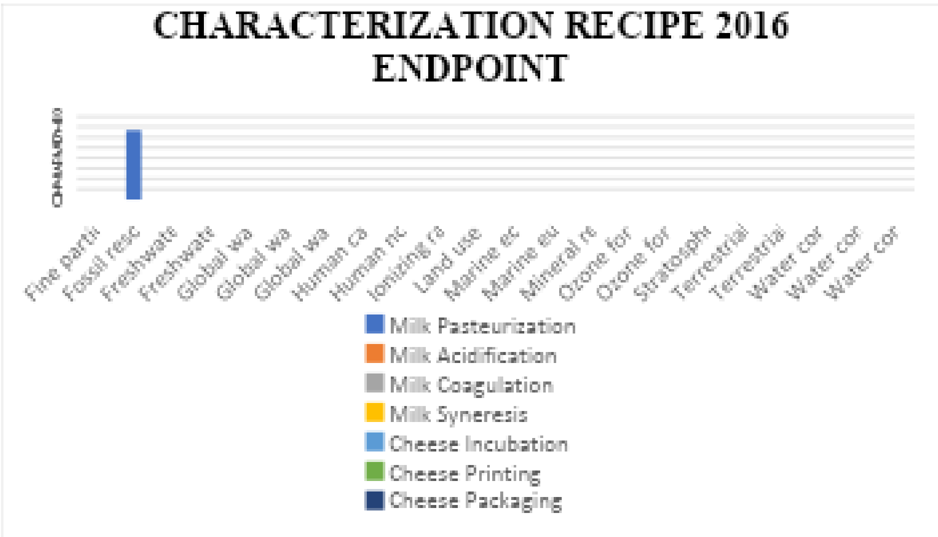

Figure 6. Analysis graph of the characterization of the cheese production process using the Recipe 2016 Endpoint method

Impact Indicators	Milk Pasteurization	Milk Acidification	Milk Coagulation	Milk Syneresis	Cheese Incubation	Cheese Printing	Cheese Packaging
Fine particulate matter formation	7,84084E-05	0	0	0	0	0	0
Fossil resource scarcity	6,67376846	0	0	0	0	0	0
Freshwater ecotoxicity	4,2787E-11	0	0	0	0	0	0
Freshwater eutrophication	5,99571E-10	0	0	0	0	0	0
Global warming, Freshwater ecosystems	1,07457E-11	5,19331E-17	2,16588E-17	4,53861E-17	4,86596E-18	1,06034E-16	1,1059E-18
Global warming, Human health	0,000130587	6,2839E-10	2,621E-10	5,49172E-10	5,88781E-11	1,28301E-09	1,33814E-11
Global warming, Terrestrial ecosystems	3,93442E-07	1,89556E-12	7,90584E-13	1,65659E-12	1,77608E-13	3,87023E-12	4,03654E-14
Human carcinogenic toxicity	4,41878E-07	0	1,5524E-17	0	0	0	0
Human non-carcinogenic toxicity	5,96766E-07	0	1,30291E-18	0	0	0	0
Ionizing radiation	5,13671E-09	0	0	0	0	0	0
Land use	5,06026E-10	0	0	0	0	0	0
Marine ecotoxicity	1,1403E-11	0	0	0	0	0	0
Marine eutrophication	4,00148E-13	0	0	0	0	0	0
Mineral resource scarcity	0,002455402	0	0	0	0	0	0
Ozone formation, Human health	2,39747E-08	0	0	0	0	0	0
Ozone formation, Terrestrial ecosystems	3,58966E-09	0	0	0	0	0	0
Stratospheric ozone depletion	1,13366E-07	0	0	0	0	0	0
Terrestrial acidification	1,93212E-07	0	0	0	0	0	0
Terrestrial ecotoxicity	1,08458E-10	0	0	0	0	0	0
Water consumption, Aquatic ecosystems	4,43428E-14	0	0	0	0	0	0
Water consumption, Human health	1,57508E-07	0	0	0	0	0	0
Water consumption, Terrestrial ecosystem	9,71699E-10	0	0	0	0	0	0

Figure 7. Characterization analysis values using the Recipe 2016 Endpoint method

At the normalization stage, the scarcity of fossil resources had the most significant impact on the cheese pasteurization process, with a value of $187009.072. The following is a graph of the normalization analysis of the cheese production process, which can be seen in Figure 8. The normalization analysis value can be seen in Figure 9.

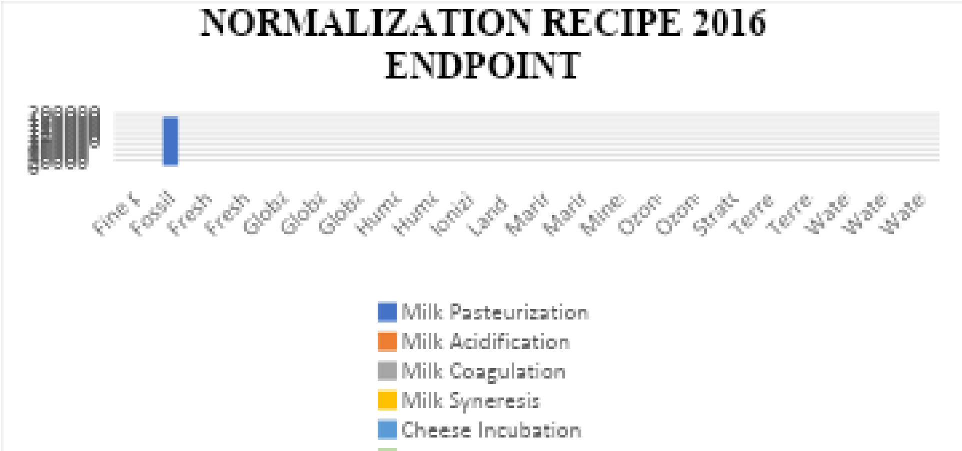

Figure 8. Analysis graph of the normalization of the cheese production process using the Recipe 2016 Endpoint method

Impact Indicators	Milk Pasteurization	Milk Acidification	Milk Coagulation	Milk Syneresis	Cheese Incubation	Cheese Printing	Cheese Packaging
Fine particulate matter formation	1,86243E-06	0	0	0	0	0	0
Fossil resource scarcity	186940,293	0	0	0	0	0	0
Freshwater ecotoxicity	3,06497E-14	0	0	0	0	0	0
Freshwater eutrophication	4,29492E-13	0	0	0	0	0	0
Global warming, Freshwater ecosystems	7,69752E-15	3,72013E-20	1,55149E-20	3,25116E-20	3,48564E-21	7,59554E-20	7,92192E-22
Global warming, Human health	3,10184E-06	1,49261E-11	6,22566E-12	1,30445E-11	1,39853E-12	3,04752E-11	3,17848E-13
Global warming, Terrestrial ecosystems	2,81835E-10	1,35785E-15	5,66321E-16	1,18667E-15	1,27226E-16	2,77237E-15	2,8915E-17
Human carcinogenic toxicity	1,04959E-08	0	3,68741E-19	0	0	0	0
Human non-carcinogenic toxicity	1,4175E-08	0	3,09479E-20	0	0	0	0
Ionizing radiation	1,22012E-10	0	0	0	0	0	0
Land use	3,62483E-13	0	0	0	0	0	0
Marine ecotoxicity	8,16837E-15	0	0	0	0	0	0
Marine eutrophication	2,86639E-16	0	0	0	0	0	0
Mineral resource scarcity	68,77876536	0	0	0	0	0	0
Ozone formation, Human health	5,69471E-10	0	0	0	0	0	0
Ozone formation, Terrestrial ecosystems	2,57139E-12	0	0	0	0	0	0
Stratospheric ozone depletion	2,69278E-09	0	0	0	0	0	0
Terrestrial acidification	1,38404E-10	0	0	0	0	0	0
Terrestrial ecotoxicity	7,76922E-14	0	0	0	0	0	0
Water consumption, Aquatic ecosystems	3,17642E-17	0	0	0	0	0	0
Water consumption, Human health	3,74128E-09	0	0	0	0	0	0
Water consumption, Terrestrial ecosystem	6,9606E-13	0	0	0	0	0	0

Figure 9. Normalization analysis values using the Recipe 2016 Endpoint method

At the stage of weighting and single score analysis, it was found that the pasteurization process was the largest source of impact with a value of 508,656,000,000 pt, with the most dominant environmental impact being resources. The following is a graph of the weighting and single-score analysis of the cheese production process, which can be seen in Figure 10. The value of the weighting and single score analysis can be seen in Figure 11.

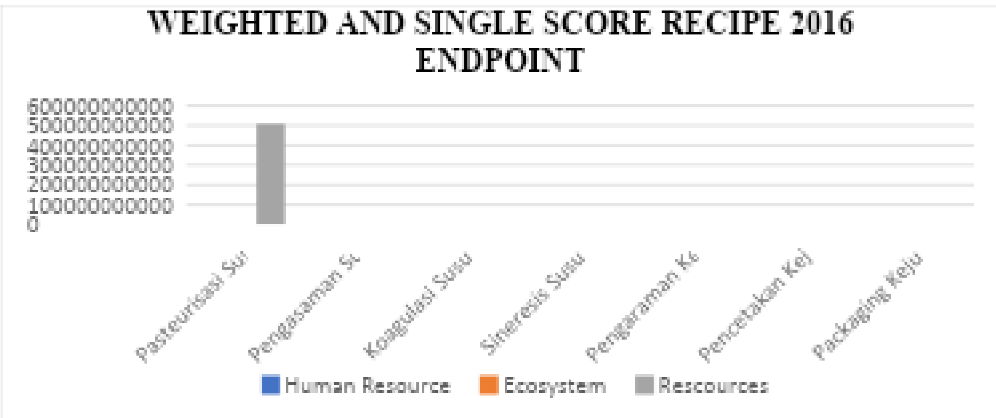

Figure 10. Analysis graph of the weighted and single score of the cheese production process using the Recipe 2016 Endpoint method

Indikator Dampak	Pasteurisasi Susu	Pengasaman Susu	Koagulasi Susu	Sineresis Susu	Pengaraman Keju	Pencetakan Keju	Packaging Keju	Total
Human Resource	0,001998427	5,97045E-09	2,49026E-09	5,21779E-09	5,59412E-10	1,21901E-08	1,27139E-10	0,001998453
Ecosystem	1,69769E-07	5,43154E-13	2,26534E-13	4,74682E-13	5,08918E-14	1,10898E-12	1,15663E-14	1,69772E-07
Rescources	5,08656E+11	0	0	0	0	0	0	5,08656E+11

Figure 11. Weighted and single score analysis values using the Recipe 2016 Endpoint method

The Life Cycle Assessment (LCA) results using the CML IA Baseline method reveal three significant environmental impacts in the pasteurization process: marine aquatic ecotoxicity (0.0000000000165743 DB-eq), acidification (0.00000000000321831 kg SO2-eq), and global warming potential (0.0000000000028027 kg CO2-eq). In contrast, the Recipe 2016 Endpoint (H) method identifies "resources" as the most significant impact category with a value of 508,656,000,000 pt. Key factors contributing to these impacts at UMKM KEJUGJA include raw material use and energy consumption in cheddar cheese production. The milk syneresis process generates 80 kg of whey waste daily, a primary concern. A fishbone diagram was developed through a literature review and discussions with UMKM KEJUGJA to address these issues, suggesting alternative strategies to reduce environmental impacts and optimize energy use in the production process. The proposed alternative used in the cheddar cheese production process is obtained from making a fishbone diagram. This fishbone diagram is based on the results of the Life Cycle Assessment (LCA) carried out and the mitigation of whey waste management, which is the main problem in UMKM KEJUGJA. In overcoming the problem of environmental impacts generated through the Life Cycle Assessment (LCA) process and the main problem of UMKM Rumah Keju Jogja (KEJUGJA), namely whey waste, the two problems are integrated into the main problem for in-depth analysis. Fishbone diagrams are used as valuable tools for analyzing these problems. This is based on the advantages of the fishbone diagram tool, namely, being able to formulate more focused and strategic solutions. The following are the results of the fishbone diagram, which can be seen in Figure 12.

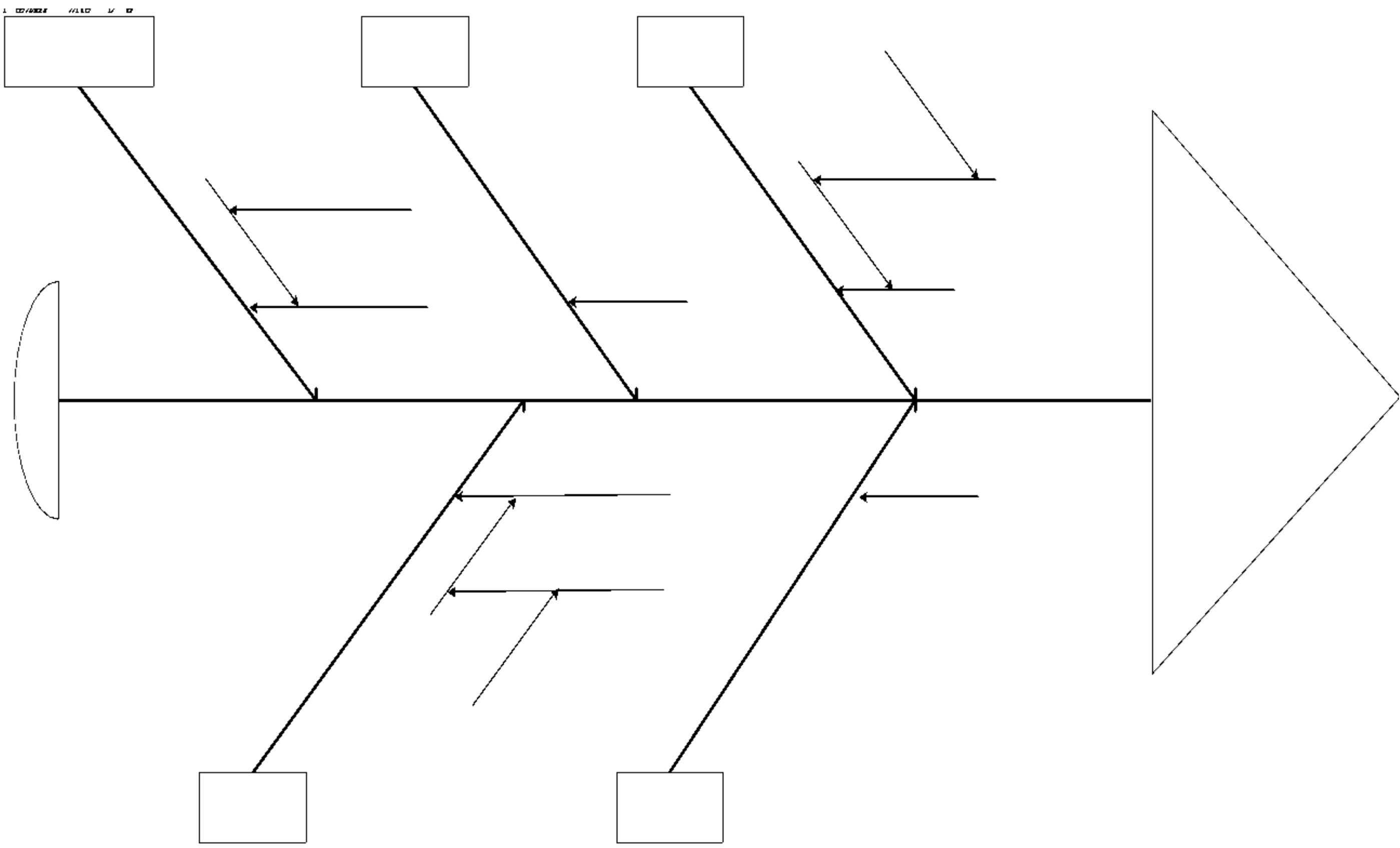

Figure 12. Fishbone diagram analysis

Through a fishbone diagram formed based on the results of interviews with UMKM KEJUGJA and literature studies that have been conducted, the proposals that UMKM KEJUGJA can provide are to provide training for workers regarding the utilization of added value from whey waste, increase cooperation with suppliers through long-term contracts, plan raw material needs using the MRP (Material et al.) method, consider using the high-temperature pasteurization method in a short time (HTST), modify the heating system on cheese VAT with more energy efficient technology, such as induction heating or heat recuperation systems, process whey waste into value-added products such as whey protein, whey-based drinks, and whey crackers, and become a supplier of whey waste as an additive in cow feed for cow's milk suppliers.

5. CONCLUSION

Based on the results of the research that has been conducted, this research produces information regarding the most significant environmental impact produced by KEJUGJA UMKM in the cheddar cheese production process. Information was obtained that the pasteurization process has the most significant environmental impact through the Life Cycle Assessment (LCA) method. Then, the information is used as input to produce alternative proposals for improvements to the pasteurization process that have the most significant environmental impact, whey waste problems, and operational problems experienced by KEJUGJA UMKM. Based on the results obtained through the fishbone diagram analysis with the 4M + 1L method (human, material, machine, method, and environment), the proposals that UMKM can give KEJUGJA to overcome the problems caused by the most significant impact through Life Cycle Assessment (LCA) in the form of the pasteurization process and whey waste that is still disposed of in the surrounding infiltration sources, namely by providing training for workers regarding the utilization of added value from whey waste, increasing cooperation with suppliers through long-term contracts, planning raw material needs using the MRP (Material Requirement Planning) method, considering using the high-temperature pasteurization method in a short time (HTST), modifying the heating system on cheese VAT with more energy efficient technology, such as induction heating or heat recuperation systems, processing whey waste into value-added products such as whey protein, whey-based drinks, and whey crackers, and becoming a supplier of whey waste as an additive in cow feed for cow's milk suppliers.

6. REFERENCES

Agustina, S. (2021). *Diktat Neraca Energi*. Jurusan Teknik Kimia.

Astuti, A. D. (2019). Analisis potensi dampak lingkungan dari budidaya tebu menggunakan pendekatan life cycle assessment (LCA). *Jurnal Litbang: Media Informasi Penelitian, Pengembangan dan IPTEK*, *15*(1), 51–64.

Bava, L., Bacenetti, J., Gislon, G., Pellegrino, L., D'Incecco, P., Sandrucci, A., Tamburini, A., Fiala, M., & Zucali, M. (2018). Impact assessment of traditional food manufacturing: The case of Grana Padano cheese. *Science of The Total Environment*, *626*, 1200–1209. https://doi.org/10.1016/J.SCITOTENV.2018.01.143

Bjørn, A., Owsianiak, M., Molin, C., & Hauschild, M. Z. (2018). LCA history. *Life cycle assessment: theory and practice*, 17–30.

Harjanto, T. R., Prastya, A., Bahri, S., & Prasadi, O. (2023). Analisis Kontribusi Pemanfaatan Limbah Kantong Semen (Reject) Berdasarkan Prespektif Life Cycle Assessment (Studi Kasus: PT. Solusi Bangun Indonesia Tbk.). *Jurnal Pengendalian Pencemaran Lingkungan (JPPL)*, *5*(2), 126–135.

Hauschild, M. Z. (2018). Introduction to LCA methodology. *Life cycle assessment: Theory and practice*, 59–66.

Irawati, D. Y., & Andrian, D. (2018). Analisa Dampak Lingkungan Pada Instalasi Pengolahan Air Minum (IPAM) Dengan Metode Life Cycle Assessment (LCA). *Jurnal Teknik Industri*, *19*(2), 166–177.

Jannah, M., & Siswanti, D. (2017). Analisis Penerapan Lean Manufacturing untuk Mereduksi Over Production Waste Menggunakan Value Stream Mapping dan Fishbone Diagram. *Sinteks: Jurnal Teknik*, *6*(1).

Juwita, R., Mizar, M. A., Taufani, A. R., Fadmasari, A. P., Diva, D. A. P., Wahyuni, E. A., Rahmi, H. N., Astarin, N. N., & Wibowo, B. S. (2022). Limbah Keju Sebagai Nata De Whey. *Prosiding Seminar Nasional Pengabdian kepada Masyarakat (SINAPMAS)*.

Khasanah, M. N., Faishal, M., & Suharyanto, T. T. (2021). Analisis Pengolahan Limbah Industri Rumah Tangga Konveksi dengan Prinsip Lean Manufacturing (Studi Kasus UKM Konveksi Kelurahan Kalitengah). *Jurnal Teknik Industri*, *11*(1), 69–76.

Negara, J. K., Sio, A. K., Rifkhan, R., Arifin, M., Oktaviana, A. Y., Wihansah, R. R. S., & Yusuf, M. (2016). Aspek mikrobiologis, serta sensori (rasa, warna, tekstur, aroma) pada dua bentuk penyajian keju yang berbeda. *Jurnal Ilmu Produksi dan Teknologi Hasil Peternakan*, *4*(2), 286–290.

Pradana, F. R., Anwar, C., Fridayani, N., Aziz, H. A., & Nurâ, A. (2017). Inovasi minuman sehat berbasis whey dan sari buah tropis. *Asian Journal of Innovation and Entrepreneurship (AJIE)*, *2*(03), 239–246.

Pravitasari, I., Hariyadi, D., & Mulyanita, M. (2020). Daya Terima Sari Kacang Hijau (Phaseolus Radiatus L) Sebagai Bahan Alternatif Pembuatan Keju. *Pontianak Nutrition Journal (PNJ)*, *3*(2), 34–38.

Riwayati, I., Hartati, I., & Harianingsih, H. (2018). Pelatihan Pembuatan Keju Lunak Alami dan Produk Olahannya Bagi Peternak Sapi di Desa Pengging Kecamatan Banyudono Boyolali. *Abdimas Unwahas*, *3*(2).

Salas-Vargas, C., Brunett-Pérez, L., Espinosa-Ortiz, V. E., & Martínez-García, C. G. (2021). Environmental impact of Oaxaca cheese production and wastewater from artisanal dairies under two scenarios in Aculco, State of Mexico. *Journal of Cleaner Production*, *311*, 127586. https://doi.org/10.1016/J.JCLEPRO.2021.127586

Vieira, D. R., Calmon, J. L., & Coelho, F. Z. (2016). Life cycle assessment (LCA) applied to the manufacturing of common and ecological concrete: A review. *Construction and Building Materials*, *124*, 656–666. https://doi.org/10.1016/J.CONBUILDMAT.2016.07.125