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Environmental impact assessment of cheese production: a systematic review of life cycle assessment studies

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Abstract

Life Cycle Assessment (LCA) research on cheese manufacturing is increasingly embracing a wider perspective and standardized approaches. Numerous studies indicate a transition from limited gate-to-gate evaluations to comprehensive life cycle analyses (either cradle-to-grave or cradle-to-retail), particularly highlighting traditional and Protected Designation of Origin (PDO) cheeses in countries like Italy, Brazil, and the United States. The choice of allocation method significantly influences these results, with studies showing climate change impacts varying from 6 to 13 kg CO_2 equivalents per kg of cheese depending on the allocation approach. Common allocation methods include dry matter content, economic value, and nutritional content, with some studies showing impact variations of up to 64% between methods. Twenty analyses evaluate the impacts of climate change, with milk production contributing to 93.5-99.6% of total impacts in certain instances. Approximately 28.3% of the climate change impacts arise from processing activities (due to energy consumption), while transport contributes 22.5%. Eutrophication and acidification are also significant factors, along with evaluations of water usage, air quality, toxicity, and resource depletion.

Keywords: *Cheese production, Life Cycle Assessment, Environmental hotspots, Allocation methods, Climate change impact.*

1. Introduction

Cheese is a dairy product traditionally derived from the milk of mammals, predominantly cattle. Given its favorable nutritional profile and its established role in human diets across cultures, global cheese production is expected to continue its upward trend in the coming years. This growth reflects both the enduring popularity of cheese as a versatile food and the evolving dietary preferences of consumers worldwide [1]. According to the Food and Agriculture Organization (FAO), global dairy trade stabilized in 2024 at approximately 85 million tonnes, following two consecutive years of decline. Within this broader context, the outlook for international cheese trade remains

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particularly promising. This steady growth underscores the resilience of global demand for cheese, even amid ongoing economic uncertainties. The increase in cheese exports appears to be driven not only by improved production conditions but also by producers' ability to adapt to the diverse preferences and expectations of international markets [2]. Cheese varieties can be classified through several technological criteria, with texture being the most widely used. This parameter—ranging from very hard, hard, semi-hard, and semi-soft to soft—is primarily determined by the cheese's moisture content [3]. Another key classification method involves the species of animal from which the milk is sourced. The distinct compositional and physicochemical properties of milk from different species significantly influence the characteristics of the resulting cheese [4]. Although cheese can be produced from the milk of various mammalian species, bovine milk remains the dominant source worldwide, accounting for approximately 85% of the global milk supply. Nonetheless, milk from sheep, goats, and buffaloes also holds commercial relevance in cheesemaking, albeit at a smaller scale [5].

Life Cycle Assessment (LCA) is a comprehensive analytical method designed to evaluate the environmental impacts associated with products or services throughout their entire life cycle [6]. Although the concept of LCA originated in the 1960s [7], its application expanded significantly during the 1990s following the development of international standardization, particularly through the ISO 14000 series (ISO 2006a, b). According to the ISO framework, LCA is structured into four standardized phases: Goal and scope definition, Life cycle inventory (LCI) analysis, Life cycle impact assessment (LCIA) and Interpretation of results.

According to ISO, the scope of a Life Cycle Assessment (LCA) - including system boundaries and level of detail - is determined by the study's purpose and subject. The Life Cycle Inventory (LCI) phase involves collecting data on inputs and outputs related to the product system. The Life Cycle Impact Assessment (LCIA) then interprets this data to evaluate potential environmental impacts. Finally, the interpretation phase analyzes results from the LCI and/or LCIA to draw conclusions, make recommendations, and support decisions in line with the study's original goals [8].

In view of these considerations, a systematic review of LCA studies applied to cheese production is essential to identify methodological trends, critical points of impact and best practices in assessing the sustainability of this sector. This study aims to address this need through a rigorous review of the existing literature.

2. Materials and Method

The present study has been developed in accordance with the ISO 14040 and ISO 14044 standards for Life Cycle Assessment (LCA) methodology (ISO (2006a)). These standards offer a globally recognized framework for conducting LCA while allowing considerable flexibility in methodology to tailor individual projects.

Twenty-five studies were analyzed on the life cycle assessment of different types of cheese from several geographical areas. Aspects of geographical and operational scope, environmental impact categories, environmental hotspots and allocation methods have been considered. The earliest study included was by [9] examining Emmental cheese production in Finland, while the most recent study was by [10] focusing on cheese production with biogas integration. This temporal range allows for a comprehensive analysis of how LCA approaches in cheese production have evolved over time. A key aspect of the research is its specificity to cheese production, rather than a broader assessment of milk production or the general dairy industry. Moreover, the primary focus remains on environmental assessment rather than economic, social, or product quality aspects, ensuring a comprehensive evaluation of the ecological footprint of cheese production.

3. Results and Discussion

3.1 Characteristics of Included Studies

This systematic examination provides insights into how LCA research in the cheese industry has evolved, highlighting trends in study scope, methodological approaches, and impact assessment priorities. The review encompasses studies from diverse geographical locations, ranging from traditional cheese-making regions in Europe to emerging cheese producers in Brazil and New Zealand, offering a global perspective on cheese production's environmental implications. The following analysis (table 1) details the key characteristics of these studies, including their focus areas, geographical scope, LCA boundaries, and the environmental impact categories they addressed.

Table 1. Characteristics and scope of reviewed LCA studies in the cheese industry

Study Focus	Geographic Region	LCA Scope	Key impact categories	Source
Cheese and whey processing	Wisconsin, USA	Farm gate to plant gate	Global warming potential, Energy intensity	[11]
Mozzarella cheese production	Northern Brazil	Gate-to-gate	Fossil Depletion, Water Depletion, Particulate Matter Formation, Photochemical Oxidants Formation, Freshwater Eutrophication, Terrestrial Acidification, Ozone Depletion, Climate Change	[12]
Minas Frescal and cured Minas cheese	Casimiro de Abreu, Rio de Janeiro, Brazil	Cradle-to-gate	Climate change, Human toxicity, Particulate matter, Ionizing radiation, Photochemical ozone formation, Acidification, Eutrophication, Water ecotoxicity, Land use, Water depletion, Resource depletion	[13]
Grana Padano cheese	Italy	Cradle-to-cheese factory gate	Climate change	[14]
Organic Parmigiano Reggiano cheese	Emilia Romagna, Italy	Cradle-to-gate	Climate change, water footprint	[15]
Small-scale cheese factory	Piloña, Asturias, Spain	Cradle-to-retail stores	Climate change, Ozone depletion, Terrestrial acidification, Freshwater eutrophication, Marine eutrophication, Human toxicity, Photochemical oxidant formation, Particulate matter formation, Terrestrial ecotoxicity, Freshwater ecotoxicity, Marine ecotoxicity, Ionising radiation, Agricultural land occupation, Urban land occupation, Natural land transformation, Water depletion, Metal depletion, Fossil depletion	[16]
44 French artisanal Protected Designation of Origin (PDO) cheeses	France	Cradle-to-gate	Climate change, Ozone depletion, Ionizing radiation, Photochemical ozone formation, Particulate matter, Acidification, Eutrophication, Land use, Water	[17]

			use, Resource use	
44 French PDO cheeses	France	Cradle-to-gate	No mention found	[18]
Cagliata cheese	Lithuania	Cradle-to-consumer	Climate change	[19]
Asiago PDO cheese	Italy	Farm gate-to-plant gate	Climate change, Energy consumption, Fresh water eutrophication	[20]
LCA tool for dairy products	Lombardy Region, Italy	Cradle-to-distribution center gate	No mention found (16 impact categories mentioned)	[21]
Grana Padano PDO and mozzarella cheese	No mention found, likely Italy	No mention found	Natural land transformation, Aquatic eutrophication, Terrestrial acidification	[22]
Cheddar and mozzarella cheese	USA	Cradle-to-grave	Climate change, Cumulative energy demand, Freshwater depletion, Marine eutrophication, Photochemical oxidant formation, Freshwater eutrophication, Ecosystems, Human toxicity, Ecotoxicity	[23]
Cheddar and mozzarella cheese	USA	Farm-gate-to-customer-gate	Climate change	[24]
Parmigiano Reggiano PDO cheese	Northern Italy, Mantua province	Cradle-to-factory-gate	Climate change, Ozone depletion, Ionising radiation, Photochemical ozone formation, Respiratory inorganics, Non-cancer and cancer human health effects, Acidification, Eutrophication, Ecotoxicity, Land use, Water scarcity, Resource use	[25]
Artisanal and industrial Minas cheese	Minas Gerais, Brazil	Cradle-to-consumer	Carcinogens, Breathing inorganic particles, Organic particles breathing, Climate change, Radiation, Depletion of the ozone layer, Ecotoxicity, Acidification/eutrophication, Land and mineral use	[26]
Different dairy farm systems for cheese production	North Italy	No mention found	No mention found	[27]
Italian mozzarella cheese	Italy	Cradle-to-grave	Climate change, Ozone depletion, Terrestrial acidification, Freshwater eutrophication, Marine eutrophication, Human toxicity, Photochemical oxidant formation, Ecotoxicity, Land occupation, Water depletion, Cumulative energy demand	[28]
Italian dairy	Veneto Region,	Varies by	Climate change, Acidification,	[29]

cheese chain	northeast Italy	manuscript: Cradle-to-farm gate, Cradle-to-dairy plant gate, Cradle-to-grave	Eutrophication, Water use, Land use, Energy usage, Ozone depletion, Toxicity, Photochemical oxidant formation, Ecotoxicity, Land occupation	
Buffalo mozzarella cheese	Italy	Cradle-to-grave	Climate change, Terrestrial acidification, Freshwater eutrophication, Marine eutrophication, Ozone depletion, Ecotoxicity, Human toxicity, Land use, Fossil depletion	[30]
Cheese production focusing on energy transition	New Zealand	No mention found	Human health, Ecosystem, Resources, Energy intensity	[31]
Cheese production comparing energy sources	New Zealand	No mention found	Human Health – Photochemical Oxidant Formation potential impact	[32]
Toma di Lanzo cheese	Lanzo valleys, Piedmont, Northwest Italy	Cradle-to-retail	Climate change, Freshwater eutrophication, Marine eutrophication, Natural land transformation, Water depletion, Fossil depletion	[33]
Emmental cheese	Finland (Toholampi, Ostrobothnian region)	Cradle-to-retail	Global warming, Eutrophication, Acidification	[34]
Cheese production with biogas integration	No mention found	No mention found	Climate change	[35]

3.2 Diversification of Impact Categories

The diversification of impact categories in LCA studies pertaining to cheese production signifies a noteworthy advancement in environmental assessment methodologies. Traditionally, researches predominantly concentrated on climate change, global warming potential, energy consumption, and fundamental resource utilization. In contrast, contemporary studies now encompass a wider array of environmental indicators, thereby facilitating a more comprehensive evaluation of the ecological footprint associated with cheese production.The impact categories most frequently assessed include climate change (20 studies), eutrophication (19 studies), acidification (12 studies), and water-related impacts (11 studies). Moreover, air quality, toxicity, land use, resource depletion, and ozone depletion have been examined in multiple studies. Comprehensive assessments, such as those conducted by Canellada et al. (2018) [16] and Lovarelli et al. (2022) [25], have broadened the scope to include up to 18 impact categories, addressing dimensions such as human health, ecosystem impacts, and resource utilization. Additionally, specialized categories, including biodiversity loss, photochemical oxidant formation, ionizing radiation, and particulate matter formation, have emerged in recent research.

3.3 Evolution of Life Cycle Assessment (LCA) Methodologies

The evolution of LCA methodologies in cheese production can be traced through distinct periods of development. Early studies (table 2) from 2003-2013 primarily concentrated on fundamental environmental impacts such as global warming potential, eutrophification, and acidification, adhering to ISO 14040/14044 standards. The field expanded between 2014-2018 to include broader considerations such as water use, land use, and resource depletion, while incorporating the ReCiPe Midpoint method. The most recent period (2019-2024) has seen further sophistication with the integration of cumulative energy demand and the adoption of the Product Environmental Footprint (PEF) method, enabling more comprehensive assessment of impacts on human health and ecosystem quality.

Table 2. Progression in life cycle assessment (LCA) methodologies and standards over three time periods

Time period	Key methodological advances	Impact categories	Standards Used
2003-2013	Focus on global warming potential, eutrophication, acidification	Limited range of impact categories	ISO 14040/14044
2014-2018	Inclusion of water use, land use, resource depletion	Expanded range of impact categories	ISO 14040/14044, ReCiPe Midpoint method
2019-2024	Integration of cumulative exergy demand, more comprehensive impact assessments	Wide range including human health, ecosystem quality	Product Environmental Footprint (PEF) method

This methodological progression is reflected in the diversity of studies conducted across different regions and production scales. Research has spanned multiple geographical contexts, from European studies focusing on Protected Designation of Origin cheeses [18] to analyses of industrial-scale production in the United States [23]. The scope has encompassed various production scales, from traditional small-scale operations [16] to large industrial facilities [19], providing a comprehensive understanding of environmental impacts across different production contexts.The advancement in LCA methodologies has enabled more nuanced analysis of environmental impacts, supporting the industry's transition toward more sustainable practices. Modern assessments now provide detailed insights into various aspects of cheese production, from raw milk production to processing operations and waste management, facilitating more targeted and effective environmental improvement strategies [36].

3.4 Environmental Impact Analysis

Table 3 presents a comprehensive breakdown of environmental impacts across different phases of cheese production, from milk production to final distribution. This analysis synthesizes findings from multiple LCA studies to quantify and characterize the environmental burden of each production phase.

Table 3. Environmental impacts across cheese production phases and their key contributors

Production phase	Primary impacts	Range of values	Key contributors
Milk Production	Climate change, Land use, Water use, Eutrophication	6.2-17.5 kg CO2 eq/kg cheese, 93.5-99.6% of total impact	Enteric fermentation, Manure management, Feed production
Cheese Processing	Energy use, Water consumption, Wastewater generation	7.1-19 MJ/kg cheese, 28.3% of climate change impact	Pasteurization, Refrigeration, Cleaning processes
Packaging	Land occupation, Resource depletion	No mention found in most studies	Material production, Disposal
Transportation	Climate change, Photochemical oxidant formation	22.5% of climate change impact	Fuel consumption, Distance traveled
Whey Management	Potential impact reduction	Up to 1.7 kg CO2 eq/kg cheese reduction	Whey utilization as animal feed or other products

The assessment reveals that milk production generates the most significant environmental impact, accounting for 93.5-99.6% of total impacts in some studies [23]. The cheese processing phase contributes notably through energy use and water consumption, with studies showing energy impacts of 7.1-19 MJ/kg cheese and accounting for 28.3% of climate change impact [14], [15], [16], [24]. Transportation also emerges as a significant contributor, responsible for up to 22.5% of climate change impacts [24], [29]. Notably, the analysis identifies potential impact reductions through improved whey management, which could decrease emissions by up to 1.7 kg CO2 eq/kg cheese [16]. This detailed breakdown of impacts across the production chain provides valuable insights for identifying environmental hotspots and developing targeted mitigation strategies in cheese manufacturing processes.

3.5 Allocation methods

Allocation methods play a key role in Life Cycle Assessment (LCA) studies in cheese production, having a significant impact on the distribution of environmental effects between different co-products such as cheese, whey and cream.

The choice of the allocation method can substantially influence the results obtained, with studies indicating that climate change impacts can range from 6 to 13 kg CO2 equivalent per kilogram of cheese, depending on the allocation approach applied [29].

Table 4 shows the allocation methods used in various studies in the field of LCA research of cheese production. Common approaches include allocation based on dry matter content, economic value and nutrient content, with some studies using multiple methods to assess the sensitivity of the results [14].

More sophisticated approaches combine subdivision with different allocation ratios to improve accuracy [11].

Also, the biophysical method recommended by the [37] has been adopted, in particular for allocating impacts between milk and meat at the farm level [25].

Table 4 - Allocation methods in cheese production life cycle assessment studies

Allocation method(s)	Note	Source
Multiple methods: subdivision, allocation ratios (total solids, nutritional content, economic value)	Combination method preferred for accuracy	[11]
Dry matter content, economic value, nutritive value	Results varied: 10.3 kg CO_2 eq (dry matter), 16.9 kg CO_2 eq (economic), 15.2 kg CO_2 eq (nutritive)	[14]
Mass balance based on dry matter content	Used for cheese/whey allocation	[15]
Substitution method	Based on nutritional content; whey considered as “fodder avoided”	[16]
Dry matter basis	No sensitivity analyses mentioned	[18]
Economic allocation	Used for raw milk, materials, and energy flows	[28]
Economic value, dry matter	Strong effect on impacts reported	[22]
Mass of milk solids, revenue-based	Including plant-level engineering assessments	[23]
Biophysical method (IDF), Physical method (dry matter)	Different methods for farm and factory level	[25]
Multiple methods: milk solids, economic, fat and protein content, no-allocation	Climate change impacts ranged 6-13 kg CO_2 eq/kg	[29]
Economic allocation	Factor: 0.87 for cheese, 0.13 for other outputs	[33]

The most common allocation methods were dry matter content-based allocation, economic value-based allocation, nutritional content-based allocation and mass-based allocation. Some studies used multiple methods to compare results and assess sensitivity, showing that the choice of allocation method can significantly affect the calculated environmental impacts.

The selection of allocation method plays a crucial role in determining environmental impact calculations. Climate change impacts can fluctuate by as much as 50%, ranging from 6 to 13 kg CO2 equivalents per kilogram, depending on the chosen allocation method. Typically, economic allocation methods lead to higher environmental impacts compared to mass-based approaches

There is a clear shift towards standardized approaches, especially in studies focused on Protected Designation of Origin (PDO) cheeses. An increasing emphasis is being placed on sensitivity analyses to evaluate the outcomes of different allocation methods. Additionally, there is a growing recognition of the importance of transparent reporting of allocation choices. Furthermore, combined approaches that integrate multiple allocation methods are being developed to enhance the accuracy and robustness of environmental impact assessments.

Emerging best practices in cheese production impact assessments include using multiple allocation methods to test result sensitivity, documenting choices transparently, and considering product-specific characteristics. Applying standardized methods, like those from the IDF, enhances consistency and improves the accuracy of environmental impact assessments.

4. Conclusion

Over the past decade, research on Life Cycle Assessment (LCA) within the cheese industry has undergone significant evolution, demonstrating an increasing focus on specificity, comprehensiveness, and broader environmental considerations. There has been a heightened emphasis on specific cheese varieties, particularly those designated with Protected Designation of Origin (PDO) status, which underscores the distinctive production processes and regional influences that affect environmental impact. Furthermore, the geographic scope of studies has broadened to include a more diverse array of cheese-producing regions across the globe. Methodologically, there is a distinct trend towards more comprehensive LCA frameworks, encompassing both cradle-to-gate and cradle-to-grave assessments, which facilitate a more holistic evaluation of environmental burdens. Researchers are also expanding their consideration of various environmental impact categories, moving beyond conventional metrics such as carbon footprint to incorporate water-related impacts and resource depletion. This transition reflects an increasing recognition of the complex sustainability challenges associated with cheese production.

The expansion of impact categories yields several advantages, including a more detailed environmental assessment, enhanced understanding of trade-offs among various sustainability concerns, and more informed decision-making regarding mitigation strategies. Furthermore, certain studies have integrated region-specific impact categories to more effectively tackle local environmental challenges. This diversification highlights the increasing acknowledgment of the intricate environmental ramifications of cheese production and reflects the ongoing transition towards more inclusive and precise sustainability assessments.

The reviewed studies suggest a trend towards more comprehensive, standardized and context-specific assessments in LCAs for cheese production. However, they also highlight the complexities of conducting LCAs in this sector and the ongoing challenges in ensuring comparability and consistency across studies

The diversity of allocation methods observed in the literature highlights the complexity of environmental impact assessment in cheese production. While this variety allows for context-specific approaches, it also underscores the need for greater standardization to improve comparability across studies. Future research would benefit from continued development of standardized allocation approaches that can accommodate the unique characteristics of different cheese production systems while maintaining comparability across studies.

Compliance with Ethics Requirements. Author declares that he respects the journal's ethics requirements.

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References

1. B. B. Soares, E. C. Alves, J. A. de Almeida Neto, and L. B. Rodrigues **(2021)**, "Chapter 8 - Environmental impact of cheese production," in *Environmental Impact of Agro-Food Industry and Food Consumption*, C. M. Galanakis, Ed., Academic Press, pp. 169–187. doi: 10.1016/B978-0-12-821363-6.00009-6.
2. "Dairy Market Review. Overview of global market developments in **2024**." Accessed: Apr. 11, 2025. [Online]. Available: https://openknowledge.fao.org/items/3be6263e-6d0b-42ee-bce4-97663f2cd905
3. T. Bintsis (**2021**), "Yeasts in different types of cheese," *AIMS Microbiol*, vol. 7, no. 4, pp. 447–470, Nov., doi: 10.3934/microbiol.2021027.
4. A. S. Shuvarikov, O. N. Pastukh, E. V. Zhukova, and P. A. Korenevskaya (**2022**), "Development of formulation for soft

cheese based on milk from animals of different species," *IOP Conf. Ser.: Earth Environ. Sci.*, vol. 954, no. 1, p. 012070, Jan., doi: 10.1088/1755-1315/954/1/012070.

5. O. Boukria, E. M. El Hadrami, S. Boudalia, J. Safarov, F. Leriche, and A. Aït-Kaddour (**2020**), "The Effect of Mixing Milk of Different Species on Chemical, Physicochemical, and Sensory Features of Cheeses: A Review," *Foods*, vol. 9, no. 9, Art. no. 9, Sep., doi: 10.3390/foods9091309.
6. I. 1440 ISO (**2006a**), *Environmental management—life cycle assessment—principles and framework.*, Geneva.
7. R. G. Hunt, W. E. Franklin, and R. G. Hunt, (**1996**), "LCA — How it came about," *Int. J. LCA*, vol. 1, no. 1, pp. 4–7, Mar., doi: 10.1007/BF02978624.
8. H. C. M. Santos, H. L. Maranduba, J. A. de Almeida Neto, and L. B. Rodrigues, (**2017**), "Life cycle assessment of cheese production process in a small-sized dairy industry in Brazil," *Environ Sci Pollut Res*, vol. 24, no. 4, pp. 3470–3482, Feb., doi: 10.1007/s11356-016-8084-0.
9. P. Voutilainen, (**2003**), *Emmental Sinileima - juuston tuotantoketjun ympäristövaikutukset ja parannusmahdollisuudet*. Jokioinen: Maa- ja elintarviketalouden tutkimuskeskus.
10. M. Casallas-Ojeda, I. Cabeza, N. Sanchez, D. M. Caicedo-Concha, and S. Astals, (**2024**), "Cheese whey and dairy manure anaerobic co-digestion at psychrophilic conditions: Technical and environmental evaluation," *Environmental Research*, vol. 251, p. 118525, Jun., doi: 10.1016/j.envres.2024.118525.
11. H. A. Aguirre-Villegas, F. X. Milani, S. Kraatz, and D. J. Reinemann, (**2012**), "Life Cycle Impact Assessment and Allocation Methods Development for Cheese and Whey Processing," *Transactions of the ASABE*, vol. 55, no. 2, pp. 613–627, doi: 10.13031/2013.41363.
12. G. F. D. A. Filho, E. B. E. Bitencourt, E. C. Ferreira, V. S. Oliveira, and G. E. Loureiro, (**2020**), "Avaliação do ciclo de vida do queijo muçarela de um laticínio na região norte do Brasil," *Revista PO: R. Eletr. de Eng. de Produção e Correlatas*, vol. 20, no. 1, pp. 316–339, Mar., doi: 10.14488/1676-1901.v20i1.3614.
13. A. A. D. Silva, L. B. Elabras-Veiga, S. L. Q. D. Souza, and M. G. Araújo, (**2023**), "Life cycle assessment of minas frescal cheese and cured minas cheese: a comparative analysis," *Food Sci. Technol*, vol. 43, p. e109522, doi: 10.1590/fst.109522.
14. L. Bava *et al.*, (**2018**), "Impact assessment of traditional food manufacturing: The case of Grana Padano cheese," *Science of The Total Environment*, vol. 626, pp. 1200–1209, Jun., doi: 10.1016/j.scitotenv.2018.01.143.
15. G. Borghesi, R. Stefanini, and G. Vignali, (**2022**), "Life cycle assessment of packaged organic dairy product: A comparison of different methods for the environmental assessment of alternative scenarios," *Journal of Food Engineering*, vol. 318, p. 110902, Apr., doi: 10.1016/j.jfoodeng.2021.110902.
16. F. Canellada, A. Laca, A. Laca, and M. Díaz, (**2018**), "Environmental impact of cheese production: A case study of a small-scale factory in southern Europe and global overview of carbon footprint," *Science of The Total Environment*, vol. 635, pp. 167–177, Sep., doi: 10.1016/j.scitotenv.2018.04.045.
17. A. Cortesi, L. Dijoux, G. Yannou-Le Bris, and C. Pénicaud, (**2022**), "Explaining the Differences between the Environmental Impacts of 44 French Artisanal Cheeses," *Sustainability*, vol. 14, no. 15, p. 9484, Aug., doi: 10.3390/su14159484.
18. A. Cortesi, L. Dijoux, G. Y.-L. Bris, and C. Pénicaud, (**2022**), "Data related to the life cycle assessment of 44 artisanally produced french protected designation of origin (PDO) cheeses," *Data in Brief*, vol. 43, p. 108403, Aug., doi: 10.1016/j.dib.2022.108403.
19. R. Dagiliūtė, I. Minkevičiūtė, and A. Dikšaitytė, (**2021**), "Life Cycle Assessment of Cheese in Terms of Climate Change," presented at the CEST2021, Athens, Greece, doi: 10.30955/gnc2021.00069.
20. A. Dalla Riva, J. Burek, D. Kim, G. Thoma, M. Cassandro, and M. De Marchi, (**2018**), "The environmental analysis of asiago PDO

cheese: a case study from farm gate-to-plant gate," *Italian Journal of Animal Science*, vol. 17, no. 1, pp. 250–262, Jan., doi: 10.1080/1828051X.2017.1344936.

21. J. Famiglietti, M. Guerci, C. Proserpio, P. Ravaglia, and M. Motta, (**2019**), "Development and testing of the Product Environmental Footprint Milk Tool: A comprehensive LCA tool for dairy products," *Science of The Total Environment*, vol. 648, pp. 1614–1626, Jan., doi: 10.1016/j.scitotenv.2018.08.142.
22. G. Gislon, L. Bava, V. Bisutti, A. Tamburini, and M. Brasca, (**2023**), "Bovine beta casein polymorphism and environmental sustainability of cheese production: The case of Grana Padano PDO and mozzarella cheese," *Sustainable Production and Consumption*, vol. 35, pp. 85–94, Jan., doi: 10.1016/j.spc.2022.10.017.
23. D. Kim, G. Thoma, D. Nutter, F. Milani, R. Ulrich, and G. Norris, (**2013**), "Life cycle assessment of cheese and whey production in the USA," *Int J Life Cycle Assess*, vol. 18, no. 5, pp. 1019–1035, Jun., doi: 10.1007/s11367-013-0553-9.
24. D. S. Kim *et al.*, (**2014**), "Life cycle assessment of cheese manufacturing in the United States.,". Accessed: Apr. 01, 2025. [Online]. Available: https://www.semanticscholar.org/paper/Life-cycle-assessment-of-cheese-manufacturing-in-Kim-Thoma/b99e73d74500444015fa5b3467a657c8ca24bfab
25. D. Lovarelli, A. Tamburini, S. Garimberti, G. D'Imporzano, and F. Adani, (**2022**), "Life cycle assessment of Parmigiano Reggiano PDO cheese with product environmental footprint method: A case study implementing improved slurry management strategies," *Science of The Total Environment*, vol. 842, p. 156856, Oct., doi: 10.1016/j.scitotenv.2022.156856.
26. E. M. Nigri, A. C. D. Barros, S. D. F. Rocha, and E. Romeiro Filho, (**2014**), "Assessing environmental impacts using a comparative LCA of industrial and artisanal production processes: 'Minas Cheese' case," *Food Sci. Technol (Campinas)*, vol. 34, no. 3, pp. 522–531, Sep., doi: 10.1590/1678-457x.6356.
27. G. Rencricca, F. Froldi, M. Moschini, M. Trevisan, S. Ghnimi, and L. Lamastra, (**2023**), "The environmental impact of permanent meadows-based farms: A comparison among different dairy farm management systems of an Italian cheese," *Sustainable Production and Consumption*, vol. 37, pp. 53–64, May, doi: 10.1016/j.spc.2023.02.012.
28. A. Dalla Riva, J. Burek, D. Kim, G. Thoma, M. Cassandro, and M. De Marchi, (**2017**), "Environmental life cycle assessment of Italian mozzarella cheese: Hotspots and improvement opportunities," *Journal of Dairy Science*, vol. 100, no. 10, pp. 7933–7952, Oct., doi: 10.3168/jds.2016-12396.
29. A. Riva, (**2017**), "Life cycle assessment of Italian dairy cheese chain,". Accessed: Apr. 01, 2025. [Online]. Available: https://www.semanticscholar.org/paper/Life-cycle-assessment-of-Italian-dairy-cheese-chain-Riva/ed4c36fc9d4b56a9cec3ce421680bfe50347e5f4
30. C. Rossi *et al.*, (**2023**), "Cradle-to-grave life cycle assessment of buffalo mozzarella cheese supply chain in central Italy," *Journal of Agriculture and Food Research*, vol. 14, p. 100871, Dec., doi: 10.1016/j.jafr.2023.100871.
31. Tarighaleslami Amir Hossein, Kambadur Sachin, Neale James R., Atkins Martin J., and Walmsley Michael R. W., (**2019**),"Sustainable Energy Transition toward Renewable Energies in the New Zealand Dairy Industry: An Environmental Life Cycle Assessment," *Chemical Engineering Transactions*, vol. 76, pp. 97–102, Oct., doi: 10.3303/CET1976017.
32. A. H. Tarighaleslami, A. Ghannadzadeh, M. J. Atkins, and M. R. W. Walmsley, (**2020**), "Environmental life cycle assessment for a cheese production plant towards sustainable energy transition: Natural gas to biomass vs. natural gas to geothermal," *Journal of Cleaner Production*, vol. 275, p. 122999, Dec. doi: 10.1016/j.jclepro.2020.122999.

33. T. Verduna, S. Blanc, V. M. Merlino, P. Cornale, and L. M. Battaglini, (**2020**), "Sustainability of Four Dairy Farming Scenarios in an Alpine Environment: The Case Study of Toma di Lanzo Cheese," *Front. Vet. Sci.*, vol. 7, p. 569167, Oct., doi: 10.3389/fvets.2020.569167.
34. P. Voutilainen, H.-R. Tuhkanen, J.-M. Katajajuuri, J. I. Nousiainen, and N. Honkasalo, "Emmental Sinileima -juuston tuotantoketjun ympäristövaikutukset ja parannusmahdollisuudet," (**2003)**. Accessed: Apr. 01, 2025. [Online]. Available: https://www.semanticscholar.org/paper/Emmental-Sinileima-juuston-tuotantoketjun-ja-Voutilainen-Tuhkanen/31b4e95fec1d9d3b93d9e2759755ff776e262d9f
35. M. Casallas-Ojeda, I. Cabeza, N. Sanchez, D. M. Caicedo-Concha, and S. Astals, (**2024**), "Cheese whey and dairy manure anaerobic co-digestion at psychrophilic conditions: Technical and environmental evaluation," *Environmental Research*, vol. 251, p. 118525, Jun., doi: 10.1016/j.envres.2024.118525.
36. İ. G. Uysal, N. Çolak Güneş, and N. Koca, (**2022**), "Farkli peynir çeşitlerinin yaşam döngüsü analizi," *Gıda*, vol. 47, no. 6, pp. 941–961, Dec., doi: 10.15237/gida.GD22062.
37. International Dairy Federation, "The IDF global Carbon Footprint standard for the dairy sector," International Dairy Federation (IDF) AISBL, Sep. **2022**. doi: 10.56169/FKRK7166.