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Perla Yetlanezi Cruz-Martínez , Lidilia Cruz-Rivero [*] , Carlos Eusebio Mar-Orozco , Ernesto Lince-Olguín , Erika Andrea Hernández , Susana Astrid López-García

Article

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Perla Yetlanezi Cruz-Martínez [1], Lidilia Cruz-Rivero [2,*], Carlos Eusebio Mar-Orozco [1], Ernesto Lince-Olguín [2], Erika Andrea Hernández [2] and Susana Astrid López-García [3]

[1] Tecnológico Nacional de México/Instituto Tecnológico de Ciudad Madero, Av. Primero de Mayo 1610, Los Mangos, 89460 Cd Madero, Tamps. Perla_MarC@hotmail.com (P.Y.C.-M.); carlos.mar.orozco@gmail.com (C.E.M.-O.)

[2] Tecnológico Nacional de México/Instituto Tecnológico Superior de Tantoyuca, División de Posgrado e Investigación. Desv. Lindero Tametate S/N La Morita, Tantoyuca, Ver 92100, México; ernesto_lince@hotmail.com (E.L-O.); erikandreah@gmail.com (E.A.H)

[3] Tecnológico Nacional de México/Instituto Tecnológico Superior de Naranjos, División de Ciencias Básicas: C. Priv. Guanajuato S/N, Manuel Avila Camacho, 92370 Naranjos, Ver; susana.lopez@itsna.edu.mx

* Correspondence: lilirivero@gmail.com; Tel.: +52 8331057073

Abstract: In this paper, we reviewed 42 studies on applied Life Cycle Analysis (LCA) in dairy products published since 2015. Such a systematic review of the literature contributes to addressing the gap regarding the usefulness of the LCA methodology and the need for additional research due to limited studies, data, variables, and the magnitude of environmental impact. We analyzed various environmental impacts generated in the environment, compared methods and results, and highlighted emerging issues affecting society, the economy, and the environment, warranting further investigation. Additionally, we statistically analyzed the effects that the choice of functional unit and allocation rule could have on the results. LCA is a key tool for assessing the environmental sustainability of the agri-food sector. This review aims to summarize case study research on LCA in dairy processing, disseminating potential environmental impacts and providing specific examples of research in dairy processing demonstrating how the representative end product is associated with environmental impacts on air, water, and land.

Keywords: environmental impact; dairy industry; sustainability

1. Introduction

The dairy industry is one of the most transcendental sectors of the economy and industrial development, in which the production of milk and cheese processing is essential since the by-products are derived from it [1].

According to data from the U.S. Department of Agriculture (USDA), global fluid milk production in 2018 reached 605.8 million tons. Of this total, 83.4% was bovine milk, while the remainder came from other species, primarily buffalo, with significant production occurring in India. [2].

According to statistical data from the Food and Agriculture Organization of the United Nations (FAO), global milk production has increased by over 59% in the last three decades, rising from 530 million tonnes in 1988 to 843 million tonnes in 2018. [3]. At this level, India is the world's largest milk producer, contributing 22% of global production. It is followed by the United States, China, Pakistan, and Brazil, respectively. [4].

The Directorate of Sectoral Economic Research and Evaluation in the agri-food panorama mentions that between 190 and 195 million metric tons of whey from milk production are extracted annually from the production of cheese, of this value, 45% are discarded in rivers, sewers, and other wastewater collection centers [5].

Therefore, the United Nations Environment Programme (UNEP) in its annual report, describes that one of the productive sectors that have the greatest impact on the environment is the agri-food industry, either for its production processes or for the different products that come to the market [6].

For its part, the Ministry of Environment and Natural Resources mentions that each industry, depending on its activity, generates waste in different percentages according to the type of product produced [7].

Likewise, the Federal Attorney for Environmental Protection states that one of the important sectors that generate considerable environmental pollution is the dairy production sector, this industry has with it a constantly growing activity, however, there are no regulations for related activities, facilities, waste management, electric energy, and water management [8].

Meanwhile, the increase in milk production and the projected global demand for dairy products in developing countries are expected to continue in the coming years [3]. Therefore, it is crucial to understand the environmental impact of the dairy industry's growth to ensure that this increase does not lead to environmental degradation. [9].

In this sense, the simultaneous consideration of the economic, social, and environmental dimensions as a whole, within the dairy industry is a fundamental issue in which mechanisms that involve the continuous improvement of the company, establish goals and objectives in the sustainable aspect, and get the organization to create awareness internally and externally, must be emphasized. it also complies with current legal requirements [10].

For this reason, nowadays the diversity and nature of processes and products in the dairy industry makes it necessary to review its environmental commitment according to the process and the product produced. Currently, the growing concern about environmental pollution generated by the possible impacts associated with manufactured and consumed products has increased interest in the development of methods, such as Life Cycle Analysis (LCA) [11].

LCA is a methodology that evaluates the environmental quality of a product or service. It studies the environmental aspects and potential impacts throughout the life of the product, from the extraction of raw materials to the final disposal of the product. It is based on the analysis of the inflows and outputs of the system, both matter and energy, including direct and indirect effects on human health, land use, and natural resources, to obtain results that show their environmental impacts, with the aim of being able to determine measures and strategies to reduce them [12].

This method defined by the International Organization for Standardization (ISO) is based on four main phases: objective and scope definition, inventory analysis (ICV), impact assessment (LCA), and interpretation of results. Each step involves several options, and each of them influences the determination of the final results of the LCA [13].

In this article, an exhaustive state-of-the-art review of 42 recently published studies was carried out, which focuses on the application of the Life Cycle Analysis methodology, which in turn satisfies criteria for the processing of dairy products, to know, compare and presents the potential environmental impacts generated in the various organizations of the agri-food sector. To finally analyze the results and benefits that have been obtained by implementing the LCA.

Likewise, to establish an overview of the current knowledge of the negative environmental effects that the dairy industry has on its production system, in this way to establish study opportunities to work in this area in the future since LCA is one of the main environmental metrics methodologies and that will potentially become a powerful strategic management and decision-making tool to make society more sustainable and efficient in the use of natural resources. Such research involved is presented here.

2. Materials and methods

The systematic literature review process was carried out according to the following stages: (1) planning, (2) conducting the review, and (3) reporting of results and dissemination

Stage 1: Review Protocol Planning

The first stage consists of the development of a review protocol, which involves planning, identifying the need, and preparing a pre-review proposal. The established protocol included information on the objectives to be analyzed in the review and a set of sample articles.

As a first step, a systematic search of scientific literature was carried out to find studies that evaluated environmental impacts using the Life Cycle Analysis (LCA) methodology in dairy products, for which two aspects were taken into account:

(a) The search strategy, and
(b) Selection criteria
(a) Search strategy

- The systematic literature search strategy began by selecting relevant keywords to characterize the scope of the study. The right choice of keywords is essential to compose the sample and ensure that the search is complete and robust. The choice was aimed at identifying previous research on the methodology of Life Cycle Analysis in the agri-food sector, specifically in the dairy industry.
- The databases selected for the literature search were Compendex, Science Direct, Scielo, Scopus, Web de la Ciencia, and Google Scholar.
- Preliminary search trials suggested that using specific keywords would be excessively restricting sample analysis. Therefore, the key concepts with the highest number of studies potentially adhering to the topic were simultaneously chosen: "LCA" (to include environmental impacts and their variations) and "milk, cheese, and/or dairy products" (to limit the search to the dairy industry).
- The keywords inserted were:

  - Life Cycle Analysis in Cheeses, Milk, Yogurt, and/or Dairy Products
  - LCA in the Dairy Industry and/or Plant
  - Life Cycle Analysis in Dairy Farms
  - Dairy life cycle analysis
  - Analysis of the life cycle in cheese
  - LCA in the dairy sector
  - LCA in the dairy industry
  - Dairy LCA

  (b) Selection criteria

- To select a set of relevant and manageable studies among the identified pieces of literature, the following selection of rules was configured:
- Inclusion of studies that have specifically assessed environmental impacts applying the Life Cycle Analysis (LCA) methodology regulated by the UNE standard in ISO 14040 version 2006-2015.
- Inclusion of studies on any category of LCA in the dairy sector (milk and dairy products such as cheese, yogurt, dairy drinks, whey by-products).
- Inclusion of studies that are related to milk production from natural dairy farming systems.
- Inclusion of all primary studies, field investigations, modeling studies or review articles available in any language (published and peer-reviewed).
- Inclusion of studies from any geographical area.
- Inclusion of studies published from 2015 to 2019.
- Exclusion from published studies, older than 5 years (before 2020).
- Exclusion of studies that do not include quantitative results, or that simply reproduce the quantitative results of others.
- Exclusion of duplicates (e.g., if a technical report was subsequently published in a peer-reviewed journal, or if the peer-reviewed paper was later included in a doctoral thesis, only the peer-reviewed article was considered).
- Exclusion of projects, technical reports, undergraduate or doctoral theses (only published and accepted articles are included).
  Stage 2: Conducting the review
- Data collection and analysis

In the second stage, a systematic review of the literature was carried out, in which the specific identification of the research, the quality assessment study, the extraction of data, and the monitoring of the progress of data synthesis were considered.

The selected articles were verified, tracing the phases of the LCA (definition of scope and objectives, inventory analysis, impact assessment, and interpretation of results) identified by the UNE standard in ISO 14040 [12].

The next step was carried out after the selection of studies (articles), which was the collection and extraction of data on the state of the art established, where the topic determined to be studied was defined, for which the following issues were taken into account:

- What are the synergies and trade-offs highlighted in the integration of Life Cycle Analysis?
- How has this issue been integrated into the dairy industry?
- How has it influenced the environment and what opportunities could be perceived?

Stage 3: Results Report and Dissemination

The data obtained were analyzed independently by the authors, to finally conclude with the theoretical writing of the information considered to be presented in the results and discussion section.

The information was summarized using the Microsoft Office software package, version 2010, and exchanged among the collaborators using e-mail

3. Results

Literature Review

3.1. Descriptive Analysis of LCA findings

Life Cycle Analysis applied to dairy production has now been identified as an important trend among the main methodological approaches to assess the level of harmonization between studies and their comparability [14].

Among the review documents that have been carried out, only those that explicitly considered the production of dairy products were retrieved. The result was 42 documents, of which 11 focused on the production of cheese of various varieties, 20 on milk production and 11 on dairy by-products derived from milk

Most of the documents withheld (28) conducted LCA studies in European countries (Spain, Italy, and Switzerland), the Americas (Brazil, Colombia, and the USA) and Oceania (mainly New Zealand), reflecting the existence of a lasting policy focus and a growing public and interest in the environmental optimization of the dairy sector in these regions.

3.1.1. Life Cycle Analysis in Cheese Production Processes.

Life Cycle Analysis (LCA) has been one of the key methodologies for assessing the environmental sustainability of the dairy sector [15]. This technique provides a systematic framework that helps to identify, quantify, and interpret the environmental impacts derived from the dairy production process, through an orderly function [16].

The main objectives of LCA studies can be divided into two main groups: descriptive and comparative. In the first group of studies, the evaluation aims to identify the environmental burdens of a selected system, while in the second group a direct comparison between two different systems [17].

The main purpose of the studies recently involved in the production processes of various types of cheese that exist in the market is to analyze the ecological, social, and economic impacts, identifying alternatives for improvement in the process to reduce these environmental impacts and thus achieve sustainable innovation at an industrial level [18].

In fact, one of the most commercialized dairy products in the world is fresh cheese, for this reason, Carranza and Oblitas [19] proposed applying the LCA methodology based on the ISO 14040 standard, to determine environmental impacts and reduce waste in the production of this product.

For his part, Canellada [20] presented an LCA and the Carbon Footprint of a traditional Asturian cheese factory, allowing the company to learn about the impacts generated by the production of Franxón cheese.

Subsequently, Laca and Diaz [21] analyzed the environmental performance of a small-scale fresh cheese factory located in northwestern Spain, in order to obtain a global view of the effects involved.

In addition, Bava, Bacenetti, Gislon, Pellegrino, and D'Incecco [22] point out that the dairy sector in Italy is recognized as one of the most environmentally impactful agricultural activities, after evaluating a study that included the production of cheese called Grana Padano.

On the other hand, in this same region, the production of pecorino cheese, obtained from the processing of sheep's milk, was evaluated [23].

Similarly, in 2017, an estimation of the environmental impact of the fourth most produced cheese in Italy called Asiago was carried out, in which the emphasis was given to the manufacturing processes and the agricultural phase, so the scenario analysis was on the allocation strategies and the aging time of the cheese [24]. In the same year, Riva et al. [25] applied an LCA to study the case of Italian mozzarella cheese. This dairy product was also analyzed by Yépez [18] in order to establish sustainable strategies for agribusiness in the city of Otavalo, Ecuador.

Within the scope of Latin American studies in a small dairy industry in Brazil, Hudson, Santos, Leonardo, De Almeida, & Brito [26] carried out a sensitivity analysis that included different fuels to generate thermal energy, strategies for cleaning utensils, and variations in the form of cheese production, using LCA.

Just as Tarighaleslami, Kambadur, Neale, Atkins, and Walmsley [27] described a quantification of the environmental profile in a New Zealand dairy industry, using the LCA methodology, they considered 3 impact categories (human health, ecosystem and resources).

In other comparative studies, diagnoses were made to contrast cheese with other dairy products already existing in the market with other regulations, being able to identify areas of improvement for companies and opportunities arose to help the design of new processes and meet consumer demand without affecting the natural ecosystem that surrounds the production environment. that is, to strengthen a company in a positive and ecologically sustainable way [16].

3.1.2. Life Cycle Analysis in Milk Production Processes

The main strength of the Life Cycle Analysis method is the perspective of systems that aim to avoid the "shift of loads" from one environmental impact to another and from one stage of production to another [17].

For this reason, the literature has led to greater acceptance of this methodology as a means of accounting for the full extent of the industry's environmental impacts, as research from LCA studies in milk is useful in promoting more responsible livestock and more sustainable production [17].

Such is the case study presented by Rivera [28] who quantified some negative environmental impacts associated with milk production in an intensive silvopastoral system - SSPi with Leucaena leucocephala (LCGP) and an intensive tropical dairy system - SILT under bs-T conditions, to estimate the generation of greenhouse gases in an industry in Colombia.

According to opportunities and gaps found in this research, a year later this study was resumed, reestimating two milk production systems and outlining more sustainable results [29].

Subsequently, Guzmán and Gutiérrez [30] developed an LCA based on the ISO 14044 standard, focused on the production of raw milk on a farm in Ubaté, Cundinamarca.

Likewise, in North America in Wisconsin, studies were developed with the main purpose of evaluating net energy intensities and greenhouse gas (GHG) emissions, by integrating dairy and bioenergy systems in land use [31]. While other analyses had a special focus on assessing impacts on human health, combining factors of a person's nutrition with the LCA framework [32].

In this way, the implementation of LCA has turned out to be global, this methodology has been extended to countries of the Oceanic continent such as the city of Waikato, New Zealand, where the environmental compensations associated with intensification methods for pasture-based milk production systems [33].

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Another more extensive case was that of Luiz, Theuvsen, and Otter [34]. who evaluated dairy cooperatives located in Mesorregião Grande Frontera de Mercosul (GFM) in southern Brazil, the area with the highest dairy production in the country, in which they identified vulnerabilities and improvements that can increase their competitiveness, using LCA.

Similarly, a further study conducted a comparison of high and low-intensification environmental impacts of dairy production systems in which they considered 53 dairy farms by means of an LCA, taking into account 2 levels of dairy production intensification with respect to agricultural production [33].

A similar analysis work under LCA guidelines was carried out in Sousse, Tunisia, evaluating the milk production of 20 dairy farms to calculate emissions (GHG) and energy consumption [35].

On the other hand, Supartono, Isman, and Yuliando [36] argue that LCA has also been implemented in Asian countries, which is why they described its contribution, which concentrated a great benefit on the production of fresh milk.

Usually, milk production studies in these regions have been carried out on a larger scale under different types of systems to obtain a better visualization of the affectations, as is the case in Iran where pasteurized milk was evaluated in 3 subsystems: feed production, dairy farm and factory of products of a dairy system [37].

Also on a smaller scale, Garg, Phondba, Sherasia, and Makkar [38] applied LCA under a multifunctional dairy system for smallholder farmers in western India.

On the other hand, in China, LCA was used to quantify the environmental impacts and resource use of milk production, in which the cow productivity system was subjected, and scenario analysis of the effects of breeding practices [39].

Later, a study of 36 intensive dairy farms was conducted, to learn about the effects of feeding system patterns on environmental impacts by a cyclic component analysis printer [40].

The recent evolution of stroke is increasing and a major boom in studies has occurred in Europe.

Mas, Pardo, Galán, and Del Prado [41] explained that they developed a case that combined a Life Cycle Analysis model to analyze emissions produced on dairy farms in northern Spain.

Trydeman, Dennis, Padel, and Hermansen [42] conducted an LCA to examine the effect of different types of dairy farms on soil and biodiversity.

In turn, another case presented was the identification of essential parameters to assess emissions (GHG) in milk production, to know the impacts, corresponding to 3 grazing systems: zero, restricted, and unrestricted [43].

In the same way, Baldini et al. [44] measured emissions from manure management operations in 3 systems, but only with a focus on Italian dairy farms.

In the same way, LCA works in Switzerland were presented, to compare an emerging technology with a common heat treatment: ultra-high temperature sterilization combined with non-aseptic homogenization [45].

Nemecek and Alig [46] also presented the results of a study of the Swiss dairy sector. They analyzed the environmental impacts of dairy farms, for 3 years, obtaining highly variable results due to factors such as cropping systems (integrated or organic).

Therefore, Jungbluth, Keller, and Meili [47] implemented LCA to understand the environmental effects of energy, water, and chemical use in more than 40 sub-processes of a dairy operation, including raw milk input.

Later in that area, another study comparing a complete grazing system, with two types of indoor feedings of fresh grass systems, was analyzed [48].

In another area, Ross, Topp, Ennos, and Chagunda [49] examined the effect of different Functional Units (UFs) applying LCA on the emission intensities of 4 livestock dairy production systems in the UK, based on 7 years of data and taking into account the environmental impacts of the whole farm systems and their milk production.

Finally, a more recent LCA application was carried out in a range of European approaches in dairy products from mixed low-crop systems of livestock, lowland, grassland-based systems, and mountain systems [50].

3.1.3. Life Cycle Analysis in Dairy By-Product Production Processes

LCA related to milk and cheese production has been studied all over the world, however, due to the great impact it has had on the dairy sector, it has called the attention of other authors in recent years to continue researching related topics, which is why within the reviewed studies were found current evaluations from 2017 to 2019 with a focus on by-products derived from milk.

A case study presented in Italy in 2017 carried out the implementation of the LCA methodology in the production of whey protein concentrates (WPC) characterized by 3 different protein concentrations (WPC35, WPC60, WPC80) in order to know the different environmental impacts caused in their generation [51].

Another recent similar example is a consistent assessment of LCA presented in a milk protein fractionation industry at the unit process level in France [52].

Meanwhile, Yan and Holden [53] applied the LCA methodology in the Irish dairy industry to analyze three dairy products: butter, skimmed milk powder, and fat powder. In addition, a year later they complemented this work, developing a study of water use efficiency in 4 Irish dairy processing plants, considering the same LCA method [54].

Risner, Shayevitz, Haapala, Goddik, and Hughes [55] used LCA to compare carbon dioxide (CO2) emissions and water use associated with the artisanal production of whey schnapps and white whiskey that uses whey as a fermentation substrate.

In addition, another aspect found was a literature review described by Görkem [56] who focused on the category of stroke studies that focus on dairy products such as milk, butter, and cheese.

4. Discussion

The main purpose of this literature review was to investigate the evolution and recent impact of Life Cycle Analysis (LCA) applied to the production of dairy products, identifying trends among the main methodological approaches to assess the level of harmonization between studies and their comparability.

Therefore, it turned out that LCA studies applied to the dairy sector have several objectives to be achieved, which is why the existence of emerging topics on which it would be worthwhile to investigate in future studies is highlighted.

It was also noted that it has led to a greater acceptance of this technique as a means of accounting for the full extent of the environmental impacts of dairy industries.

Consequently, understanding the current research, the direction of LCA studies in dairy production, and the summary of their results will be useful in promoting responsible and sustainable livestock production from environmental, social, and economic perspectives.

The high prevalence of LCA methodology is surprising, considering the search strings employed, finding elements of LCA in all the studies reviewed indicates a consensus that they are necessary to quantify the environment.

The interpretation is that Life Cycle Analysis is widely viewed as essential to capture the relevant environmental consequences in dairy industry processes.

On the other hand, it was also detected that LCA applied in milk production has attracted attention in recent years, but the results are often discordant and conditioned by the choices of the practitioners. This has clearly made it difficult to identify the most environmentally friendly way to produce milk.

The various authors make it clear that two types of environmental impact are considered during the Life Cycle of a product: the use of resources such as land or fossil fuels, and the emission of pollutants such as ammonia or methane (inputs and outputs of the system under study). Such pollutant emissions contribute to impact categories, such as climate change, acidification, eutrophication, human health, or ecotoxicity.

Depending on the objectives, stroke studies can be divided into two groups: descriptive and comparative. Therefore, in the first group of studies, the evaluation aims to identify the environmental burdens of a selected system, while in the second group, it carries out a direct comparison between two different systems.

Among the articles reviewed, 35 are descriptive (ID) and 7 are comparative (C).

On the other hand, the influence of the management options of general agricultural strategies has been considered an interesting topic, as well as the different options of farmers, which reflect having different impacts on the environment.

This argument was addressed in a number of ways. Some authors compared a priori two management options such as different levels of intensification, breeds, or feeding regimes. Other authors tackled the problem a posteriori by considering a large number of farms and trying to evaluate the characteristics of the farm that most influence the results.

Finally, other authors emphasized the economic aspect of management options, with an eco-efficiency assessment.

Other recurring themes were the evaluation of changes in the method: different allocation rules, systems, limits, or approaches. It is interesting to note that other authors also mentioned these problems, but without reporting them in the scope of the study.

Also, some difficulties in reaching a shared approach arose when observing the citation of the reference standards used, such as the UNE standard in ISO 14040, which establishes the environmental assessment methodology that allows examining and quantifying the potential environmental aspects of a product or service throughout its life cycle. that is, of all the stages of its existence, it was not always considered by the authors and it was perceived that only some studies followed the method of complete stroke in all its phases.

Among the selected studies, only 18 clearly stated that they followed ISO standards in their assessment; The studies mentioned it generically, while 24 studies did not cite it at all.

The reference or lack of reference to ISO standards cannot be considered as an indicator of the level of knowledge of the LCA method, nor as a guarantee of the reliability of the results, but it is interesting to note that some authors did not take these documents into account when preparing a scientific publication.

This could be due to the general nature of the principles included in the ISO, which do not respond to the specific problems related to the dairy sector (functional unit, system limits, multifunctionality management).

On the other hand, in order to analyze similar studies, two ways of performing a stroke were considered: consequential and attributional. Consequentials aim to quantify the environmental consequences of a change in demand for a product. And attributionals, which aim to quantify the environmental impact of a product. Therefore, only attributional studies were included.

Ideally, an LCA assesses the environmental impact of a product throughout its life cycle, i.e., from cradle to grave. Most LCA studies, however, evaluated only stages of production up to the farm gate and failed to succeed at stages such as processing, retail or home, and recycling.

We included studies, therefore, that assessed at least all stages from the production of raw materials to the manufacture of the products. (Crib to the door).

Studies that looked at more stages after the industry gate were included, however, some studies that were excluded met the selection criteria, but no data were available.

On the other hand, LCA relates the environmental impact to a functional unit (UF) which is the measure of the main function of the production system, expressed in quantitative terms, and gives a reference of what are the related inputs and outputs. Likewise, in agricultural production systems, the function is to produce food, in this case, it is considered per kg or per liter of fresh product produced.

Consequently, a UF depends on the function of the product, and the main function of dairy-livestock products is to satisfy the human being, specifically speaking of the need for the nutrition of the body, especially the obtaining of proteins. That is why, in this context, the authors considered 1 kg of produced product (milk, corrected milk fat-protein, cheese, or other dairy derivative) as a UF.

Another situation mentioned is the case of production systems in which a company that manufactures various products or involves different processes, will find itself in situations of multiple outputs to the environment and the impact of the production system or process must be assigned to several outputs.

To this end, the studies mention three main allocation methods applied: economic allocation, physical allocation, and system expansion. The most widely used in the works was economic allocation, in which the environmental impact of a process output is assigned to its multiple outputs based on their relative economic value.

That is why LCA results based on different allocation methods cannot be directly compared.

At the same time, another point of debate is the definition of a common Functional Unit. The choice to express the environmental product per kilogram or per hectare of land can alter the conclusions, favoring one or the other production of the system. Also, a single metric doesn't work completely. Describing the various results delivered by dairy farms could be an inadequate measure of their environmental impacts. This observation opened an interesting debate, still unresolved, about which is the most appropriate Functional Unit to adopt among stroke professionals.

Regarding the issue of selecting environmental impact categories to be evaluated, the situation arose that the authors differ that such publications can be a complete LCA or a simplified version. A common type of simplified LCA is one that focuses solely on assessing an environmental impact, i.e., a specific category.

Therefore, within the group of 42 publications, (22) studies cover one or two indicators at the inventory level (energy and/or water use) to evaluate one, two, or three categories.

A substantial number of studies (12) limited themselves to taking into account only the category of climate impact without considering other environmental problems. This practice does not fully comply with the principle, claimed in the ISO standard, 14040, of avoiding the change from one potential environmental problem to another due to the lack of an overview of environmental impacts.

In this way, it was found that the most studied impact category was marine eutrophication referred to in 24 publications, the second category was terrestrial acidification indicated in 23 publications, then climate change indicated in 22 studies, consecutively the ozone layer and water footprint both studied in 18 publications, GHG emissions indicated in 15, Soil transformation and photochemical oxidant formation were studied in 13, ecotoxicity and impacts on human health were studied in 12, the use of minerals and fossils in 11, followed by global warming potential with a time horizon of 100 years (GWP100) and ionizing radiation in 10. Further impact categories/inventory indicators were studied in three or fewer publications.

LCAs were found to include a greater number of environmental impact categories over time. However, in the recent analysis, there are still relatively few publications with strokes of 7 or more impacts.

In terms of simplified LCAs, they found a livestock-on-farm approach, in which studies that aimed to know their GHG emissions and climate change in depth are quantitatively examined, but other impact categories are seriously lacking. That is why it is highlighted that the impact of climate change is a critical element in livestock pipeline systems; however, focusing on this impact category is insufficient to define a complete LCA.

In addition, intrinsically in the literature, it was found that dairy manufacturing is the next most significant stage of GHG environmental impact in the dairy product life cycle, second only to agricultural production.

It is argued that the technology to lessen or eliminate the environmental impact of dairy processing is available and there are many examples of the success of renewable energy in GHG mitigation and wastewater treatment by alternative technologies.

There is potential for additional environmental impact, improved through alternative processing. However, there are realities in the sector that hinder the implementation of alternative technologies, such as the high cost of introducing these improvements, which are exaggerated by the low price margin of the dairy industry.

In addition, the uncertainty of predicting the quality of the product from the complexity of the dairy substrate as a food matrix is also a factor when a new technology is implemented and, therefore, it adds to the risk of expanding alternative technologies, with the fear that the largest amount of dairy products are minimally processed and of quality, so the perception and expectation of consumers has been shaped by the products themselves and distribution practices.

On the other hand, publications focused on climate change or a more limited set of impact categories such as resource depletion, eutrophication, acidification, and land use often recommend management practices or policies that encourage system intensification to reduce GHG emissions, discourage production on traditional grazing lands, and increase dependence on grain and forage crops.

The elimination of livestock grazing from ecosystems with long histories such as semi-natural grasslands causes the ecosystem to convert to another vegetative state and thus can alter the species composition and habitat for keystone species or species of interest.

Also, policies that promote feeding livestock oils and grains to increase animal production and decrease emission intensity, such as the carbon farming initiative and the greenhouse gas reduction program, can jeopardize biodiversity due to intensive farming, as they are practices that, in addition to changing land use, they can lead to competition for limited water resources and harmful nutrient runoff.

Subsequently, the use of water was seen as a worrisome consumption, since the efficiency and conservation of water with industrial processing have been analyzed alertly when scarcity reaches the limits, and this problem drives the investment economy.

Another factor arises in some cases when there are large populations that assume a greater demand for water, as well as seek quality of effluents, this element contributes even more to the increase in the economy for the dairy process. For this reason, this can put pressure on the justification of a dairy infrastructure within a commercial area and can contribute to unfavorable market returns.

The European continent is a clear example where there are large populations and when operating dairies they would have some difficulties, resulting in competition for limited available resources.

For some arid parts of the world, researchers have suggested not investing in expensive water technologies. On the other hand, countries with an excess of water could choose to take advantage of such a resource and implement a more sustainable system for the dairy sector, as a net effect some import of an equivalent amount of water to arid countries could also coexist, to support the economy of that sector.

Technological capacity for wastewater at the treatment site is extensive and widespread across many industries and one of the important goals is to reduce BOD from water discharges. Opting for anaerobic treatment since, unlike aerobic wastewater treatment, digestion can be set up to provide methane, which can be used to generate heat or energy through combustion, as long as most of the methane generated is from agricultural carbon, would be considered a renewable energy source and therefore could offset GHGs as a contribution from the installation of innovative dairy processing.

Table 1 summarizes the prevalence of categories and inventory indicators covered in more than three studies. Unfortunately, ionizing radiation has only been considered in 4 of the reviewed publications. Biodiversity loss should also be an important impact category in many studies of dairy processing and has only been included in 1 study reviewed.

Table 1. Cheese, Milk and Dairy Inventory Categories and Indicators in General.

PAPER	AUTHORS	YEAR	COUNTRY	ELEMENT	SOFTWARE	F. UNIT	SCOPE	IMPACTS
LIFE CYCLE ANALYSIS (LCA) OF MOZZARELLA CHEESE, AS A STRATEGY FOR SUSTAINABLE AGRIBUSINESS: A STUDY AT THE ANDILACTEOS COMPANY IN THE CITY OF OTAVALO.	J.M. Yépez Pesántez	2018	ECUADOR	CHEESE	Software ArcGIS 10.2	1 Kg	From the cradle to the grave	Water consumption. Energy consumption. Wastewater, CH4 and CO2 emissions.
LIFE CYCLE ANALYSIS AND CARBON FOOTPRINT IN A TRADITIONAL ASTURIAN CHEESE FACTORY	F. Canellada Barbón	2017	SPAIN	CHEESE	Software SimaPro v7 EcoInvent y LCA Food	1kg	From the farm gate to the cheese plant gate	Climate change, Ozone Depletion, Human Toxicity, Ecotoxicity,
GENERATION OF A WASTE REDUCTION PROGRAM FOR THE EVALUATION OF THE ENVIRONMENTAL IMPACT OF THE FRESH CHEESE PROCESS USING LIFE CYCLE ANALYSIS AND ARTIFICIAL INTELLIGENCE	E. Torres Carranza & J.Oblitas Cruz	2017	PERU	CHEESE	Matlab and Forest Software	1 Kg	From door to door	Global greenhouse gas emissions
THE ENVIRONMENTAL ANALYSIS OF ASIAGO PDO CHEESE: A FARM-TO-GATE CASE STUDY	A. Dalla Rivaa , J. Burekb, D. Kimb, G. Thomab, M.Cassandroa & M. De March	2017	ITALY	CHEESE	SimaPro 8.1.1, Ecoinvent VR 3.1 and Monte Carlo 1.00 software	1 Kg	From the farm gate to the cheese plant gate	Climate change, ozone depletion, terrestrial acidification, freshwater eutrophication, toxicity, formation of photochemical oxidants, land occupation and water depletion.
ENVIRONMENTAL IMPACT OF CHEESE PRODUCTION: A SMALL-SCALE CASE STUDY OF A FACTORY IN SOUTHERN EUROPE AND A GLOBAL VIEW OF THE CARBON FOOTPRINT	F. Canellada, A. Laca, A.Laca & Mario Diaz	2017	SPAIN	CHEESE	software LCA SimaPro v8 y ReCiPe Midpoint (H) V1.12	4770 Kg	From the cradle to the retail stores	Climate change, terrestrial acidification, eutrophication of fresh and marine water, human toxicity, formation of photochemical oxidants, particle formation, terrestrial ecotoxicity, ecotoxicity of fresh and marine water, ionizing radiation, occupation of

Title	Authors	Year	Country	Product	Software/Method	Functional Unit	System Boundary	Impact Categories
ENVIRONMENTAL LIFE CYCLE ASSESSMENT OF ITALIAN MOZZARELLA CHEESE: CRITICAL POINTS AND OPPORTUNITIES FOR IMPROVEMENT	At. Dalla Riva, J. Burek, D. Kim, G. Thoma, M. Cassandro & M. De Marchi	2017	ITALY	CHEESE	Ecoinvent v3.2 y SimaPro 8.1	1 Kg	From the cradle to the grave	agricultural and urban land, natural soil transformation, water dehydration. Climate change, pent-up energy demand, land occupation, terrestrial acidification, freshwater and marine eutrophication, ecotoxicity, human toxicity, ozone depletion, water depletion, and photochemical oxidant formation.
IMPACT ASSESSMENT OF TRADITIONAL FOOD MANUFACTURING: THE CASE OF GRANA QUESO PADANO	L. Bava, J. Bacenetti, G. Gislon, L. Pellegrino, P. D'Incecco, A. Sandrucci, A. Tamburini, M. Fiala, M. Zucali	2018	ITALY	CHEESE	Software Cornell Penn Miner y ILCD 2011-Midpoint V1.03	1 kg	From the cradle to the door of the cheese factory	Climate change, ozone depletion, particle formation, photochemical ozone formation, terrestrial acidification.
ENVIRONMENTAL HOTSPOTS AND IMPROVEMENT SCENARIOS FOR TUSCAN "PECORINO" CHEESE USING LIFE CYCLE ASSESSMENT	G. Mondello, R. Salomone, E. Neri, N. Patrizi, S. Bastianoni & F. Lanuzza	2018	ITALY	CHEESE	SimaPro 8.0.2 and ReCiPe Midpoint (H) Software, Version 1.09	1 kg	From the cradle to the door	Climate change, ozone depletion, terrestrial acidification, eutrophication of fresh and marine water.
GREEN CHEESE: PARTIAL LIFE CYCLE ASSESSMENT OF GREENHOUSE GAS EMISSIONS AND ENERGY INTENSITY OF INTEGRATED MILK PRODUCTION AND BIOENERGY SYSTEMS	H. A. Aguirre Villegas, TH Passos Fonseca, DJ Reinemann, LE Armentano, MA Wattiaux, VE Cabrera, JM Norman & R. Larson	2015	UNITED STATES	CHEESE	Gabi and SimaPro LCA software	1 Kg	From the cradle to the farm gate	GHG, depletion of abiotic resources, energy depletion, land use,
LIFE CYCLE ASSESSMENT OF THE CHEESE PRODUCTION PROCESS IN A SMALL DAIRY INDUSTRY IN BRAZIL	C. Hudson M Santos, H. Leonardo Maranduba, José A. de Almeida Neto, & L. Brito Rodrigues	2016	BRAZIL	CHEESE	SimaPro 8.0.5.13 and Ecoinvent 3 software	1 Kg	From the cradle to the door	Climate change, ozone depletion, terrestrial acidification, freshwater eutrophication, photochemical oxidant for particle formation, water depletion and soil depletion.

Title	Authors	Year	Country	Product	Software	Functional unit	System boundary	Impact categories
LIFE CYCLE ANALYSIS OF THE PRODUCTION OF FRESH CHEESE WITH ARTISANAL RECIPE, BUT WITH MODERATELY INDUSTRIAL PRODUCTION, IN A SUSTAINABLE WAY IN THE ECUADORIAN AUSTRO	L. Alvarado, Mercy A. Montalván, Chumy, Nelson, I., Naspud M. Rojas, E., Vera Castro	2015	ECUADOR	CHEESE	Software Ecoinvent	1 kg	From the cradle to the grave	GHG, acidification, eutrophication, resource depletion
ANALYSIS OF THE LIFE CYCLE OF RAW MILK PRODUCTION AS A TOOL TO DETERMINE THE IMPACTS ON HUMAN HEALTH, ECOSYSTEM QUALITY AND RESOURCES. CASE STUDY, FINCA SAN FRANCISCO, VEREDA PATERA CENTRO, MUNICIPALITY OF UBATÉ – CUNDINAMARCA	Luisa María Guzmán Vargas & Fernando Gutiérrez Fernández	2016	COLOMBIA	MILK	Sima Pro 8.0.5.13 and Eco-indicator 99 software	1000 liters	From the cradle to the door	Carcinogenic, organic and inorganic substances Ecotoxicity, Climate change Ozone depletion, acidification-eutrophication
LIFE CYCLE ANALYSIS FOR BOVINE MILK PRODUCTION IN AN INTENSIVE SILVOPASTORAL SYSTEM AND A CONVENTIONAL SYSTEM IN COLOMBIA	J.E. Rivera, J. Chará & R. Barahona	2016	COLOMBIA.	MILK	Software SimaPro	1 kg	From the cradle to the door of the estate	Land use (US), non-renewable energy use (UENR), and greenhouse gas (GHG) emissions and global warming potential.
LIFE CYCLE ANALYSIS (LCA) IN AN INTENSIVE SILVOPASTORAL SYSTEM (SSPI) AND A CONVENTIONAL INTENSIVE SYSTEM ORIENTED TO MILK PRODUCTION UNDER BS-T CONDITIONS	J.E. Rivera	2015	COLOMBIA	MILK	SimaPro Software (Pre Consultants, 2008).	1 kg	From the cradle to the door	Land use (US), non-renewable energy use (NFU), and greenhouse gas (GHG) emissions.
ENVIRONMENTAL IMPACTS AND RESOURCE USE OF MILK PRODUCTION IN NORTHERN CHINA PLAIN, BASED ON LIFE CYCLE ASSESSMENT	Xiaoqin Wang, tewart Ledgard, Jiafa Luo, Yongqin Guo, Zhanqin Zhao, Liang Guo, Liu Song, Nannan-Zhang, Xuegin Duan &Lin Ma	2018	CHINA	MILK	Ecoinvent v3.0.	1 kg	From the cradle to the farm gate	Global Warming Potential (GWP), Eutrophication Potential (EP), Acidification Potential (AP), Non-Renewable Energy Use (NREU), Land Use (LU), Blue Water Use (BWU; Water Withdrawal), and Land Occupation.

LIFE CYCLE ANALYSIS OF RAW MILK PRODUCTION IN TUNISIA	Amira Gazouani, Nacheur M'Hamdi, Ibrahim-El Akram Znaidi, Cyrene Darej, Norchene Guoia, Marauua Hasnaui, Rachid	2018	BEN AROUS TÚNEZ	LECHE	Holos Software (Version 2.2) and simaPRO Version 7.1	1kg	From the cradle to the farm gate	Energy consumption, agricultural and urban land use, climate change, water use.
THE IMPORTANCE OF INCLUDING SOIL CARBON CHANGES, ECOTOXICITY AND BIODIVERSITY IMPACTS IN ENVIRONMENTAL LIFE CYCLE ASSESSMENTS OF ORGANIC AND CONVENTIONAL MILK IN WESTERN EUROPE	Marie Trydeman Knudsen a, Teodora Dorca Preda Sylvestre Njakou Djomo, Nancy Peña, Susanne Padel, Laurence G. Smith, Werner Zollitsch, Stefan Hörtenhuber, John E. Hermansen	2019	WESTERN EUROPE	MILK	SimaPro and Ecoinvent 3.3 Software	1 kg	From the cradle to the farm gate	"Climate change, acidification, marine eutrophication, terrestrial eutrophication, freshwater ecotoxicity and land use.
LIFE CYCLE ASSESSMENT OF MILK PRODUCTION: A COMPARISON BETWEEN ESTIMATES AND INVENTORY OF EMISSIONS MEASURED FOR MANURE MANAGEMENT	C. Baldini, L. Bava, M. Zucali & M. Guarino.	2018	ITALY	MILK	SimaPro PhD Software 8.4.0.0 (PRé Consultores, 2016) and Ecoinvent® 3.3	1 kg	From the cradle to the farm gate,	Global warming, acidification, particulate matter formation, photochemical ozone formation, terrestrial and marine eutrophication, depletion of mineral, fossil and renewable resources.
ASSESSMENT OF THE CONSEQUENTIAL LIFE CYCLE OF PASTURE-BASED MILK PRODUCTION	Jeerasak Chobtang, Sarah J. McLaren, Stewart F. Ledgard & Daniel J. Donaghy.	2016	NEW ZEALAND	MILK	Software SimaPro v8 (Pré Consultants 2013) y ecoinvent v3	1 kg	From the cradle to the farm gate	Ozone depletion potential; Human Health Ecotoxicity for aquatic freshwater.
LIFE CYCLE ASSESSMENT OF PASTURE-BASED DAIRY PRODUCTS. PRODUCTION SYSTEMS IN SWITZERLAND	Zumwald J., Braunschweig M., Nemecek T., Schüpbach B., Jeanneret Ph., Roesch A., Hofstetter P. & Reidy B.	2018	SWITZERLAND	MILK	*Ecoinvent v3.0.	1 kg	From the cradle to the farm gate	Water use, soil, resources, non-renewable energy use, deforestation, global warming potential, acidification, eutrophication, terrestrial and marine, terrestrial and marine ecotoxicity, human toxicity, ozone formation, biodiversity, landscaping.

Title	Authors	Year	Country	Product	Software/Method	Functional Unit	System Boundary	Impact Categories
CARBON FOOTPRINT AND BIODIVERSITY ASSESSMENT IN DAIRY PRODUCTION	Marie Trydeman Knudsen, Sanna Hietala, Peter Dennis, Susanne Padel & John E. Hermansen	2016	UNION EUROPEA	MILK	*Software SimaPro	1 liter	From the cradle to the farm gate	Climate change, greenhouse gases and potential damage to biodiversity.
LIFE CYCLE ENVIRONMENTAL IMPACTS OF HIGH AND LOW INTENSIFICATION PASTURE-BASED MILK PRODUCTION SYSTEMS: A CASE STUDY FROM WAIKATO REGION, NEW ZEALAND	Jeerasak Chobtang, Stewart F. Ledgard, Sarah J. McLaren & Daniel J. Donaghy	2016	NEW ZEALAND	MILK	statistical analysis software, SAS ®9.4 and European Food SCP	1 kg	From the cradle door to the farm	Climate change, ozone depletion potential, Particulate matter, ionizing irradiation, photochemical Ozone formation potential, acidification potential, Terrestrial eutrophication potential, freshwater eutrophication potential, marine eutrophication potential
LIFE CYCLE ASSESSMENT OF 36 BY-PRODUCT FED DAIRY FARMS IN SOUTHWEST CHINA	Lin Wang, Akira Setoguchi, Kazato Oishi, Utah Sonoda aHajime Kumagai, Chagan Irbis, Tatsuya Inamura & Hiroyuki Hirooka.	2019	CHINA	MILK	SAS 9.3 (2008)	1 Kg	From the cradle to the farm gate	Global warming potential (GWP), acidification potential (AP), eutrophication potential (EP) and energy consumption (EC).
A LIFE CYCLE ASSESSMENT FRAMEWORK THAT COMBINES NUTRITION AND THE ENVIRONMENTAL IMPACT OF DIET ON HEALTH: A CASE STUDY ON MILK	Katerina S. Stylianou, Martin C. Heller, Victor L. Fulgoni, Alexi S. Ernstoff, Gregory A. Keoleian & Olivier Jolliet	2016	USA	MILK	Ecoinvent v3.0. y Monte Carlo	1 Kg	Door to door	Greenhouse gas emissions, global warming, particulate matter, climate change, water consumption and quality (eutrophication), land use, ecosystem quality, resource use, ecosystem services, and human health potential.
ORGANIZATIONAL STRUCTURES AND THE EVOLUTION OF DAIRY COOPERATIVES IN SOUTHERN BRAZIL: A LIFE CYCLE ANALYSIS	Caetano Luiz Beber, Ludwig Theuvsen & Nutria Verena	2018	BRAZIL	MILK	*Ecoinvent	*1 Kg	*From the cradle to the door of the dairy cooperative	*Climate change, greenhouse gases and potential damage to biodiversity.

Title	Authors	Year	Country	Product	Method/Software	Functional Unit	System Boundary	Impact Categories
ASSESS DAIRY FARM SUSTAINABILITY USING FARM-WIDE MODELS AND LIFE CYCLE ANALYSIS	K. Mas, G. Pardo, E. Galán & A. del Prado	2016	SPAIN	MILK	*Software SimaPro	1 Kg	*From the cradle to the farm gate	Greenhouse gases, eutrophication, acidification, water footprint, land use and fertility index.
IMPLEMENTATION OF LIFE CYCLE ASSESSMENT IN FRESH PASTEURIZED MILK PRODUCTION	W Supartono, M Isman & H Yuliando.	2019	INDONESIAN	MILK	*Software SimaPro	1 liter	From the cradle to the grave	Greenhouse gases, global warming potential, acidification potential, and eutrophication.
LIFE CYCLE ASSESSMENT OF DAIRY PRODUCTION SYSTEMS IN WAIKATO, NEW ZEALAND	Stewart F Ledgard, Jeerasak Chobtang, Shelley Falconer & Sarah McLaren	2016	New Zealand		EC-JRC-IES (2011), European Food SCP	1 kg	From the cradle to the farm	Ecotoxicity in fresh and marine water. GHG gases, climate change. Acidification, eutrophication, human health.
LIFE CYCLE ASSESSMENT OF DAIRY PRODUCTION SYSTEMS IN SWITZERLAND: STRENGTHS, WEAKNESSES AND MITIGATION OPTIONS	Thomas Nemecek & Martina Alig	2016	SWITZERLAND	MILK	Ecoinvent	1 Kg	From the cradle to the farm gate	Global warming, ecotoxicity, eutrophication and acidification potential, water use, energy and land use, climate change, ozone formation, human toxicity and biodiversity.
RELATIVE EMISSION INTENSITY OF DAIRY PRODUCTION SYSTEMS: USING DIFFERENT FUNCTIONAL UNITS IN LIFE CYCLE ASSESSMENT	S. A. Ross, C. F. E. Topp, R. A. Ennos & M. G. G. Chagunda	2016	UNITED KINGDOM	MILK	*Mental Panel on Climate Change (IPCC)	1 Kg	From one o'clock to the farm gate	Greenhouse gases, land use, climate change, energy use and water resources.
WHEY PROTEIN CONCENTRATE (WPC) PRODUCTION: ENVIRONMENTAL IMPACT ASSESSMENT	Jacopo Bacenetti, Luciana Bava, Andrea Schievano & Maddalena Zucali	2017	ITALY	WHEY PROTEIN CONCENTRATE	Ecoinvent version 3 and Geneva	1 Ton	From one to the door of the industry	Climate change, ozone depletion, particulate matter, formation of photochemical oxidant, acidification, eutrophication of fresh water, terrestrial and marine eutrophication depletion of mineral, fossil and renewable resources.
CHEESE WHEY FERMENTATION AND DISTILLATION: CARBON DIOXIDE EQUIVALENT,	Derik Risner, Avi Schevitz, Karl Hapla,	2018	UNITED STATES	FERMENTED WHEY	Software WARM (EPA, 2016)	750 ml	From the cradle to the door of industry	Greenhouse gases, land use, climate change, energy use and water resources.

EMISSIONS AND WATER USE IN THE PRODUCTION OF WHEY SPIRITS AND WHITE WHISKEY	Lisbeth Meunier prose, & Paul Hughes						
TRANSITIONING FROM SUSTAINABLE ENERGY TO RENEWABLE ENERGY IN NEW ZEALAND'S DAIRY INDUSTRY: AN ENVIRONMENTAL LIFE CYCLE	Amir Hossein Tarighaleslami, Sachin Kambadur, James R. Neale, Martin J. Atkins & Michael RW Walmsley	2019	NZeeland	CHEESE	Monte Carlo, NREL Database, 2014 and openLCA 1.7.4	1 kg	*From door to door	Ozone depletion, formation of photochemical oxidant, impacts on human health, ecotoxicity of fresh and marine water, depletion of fossil resources,
MULTI-PRODUCT DAIRY PROCESSING LIFE CYCLE ASSESSMENT WITH IRISH BUTTER AND MILK POWDERS AS AN EXAMPLE	Mingjia Yan & Nicholas M. Holden	2018	Ireland	BUTTER AND POWDERED MILK	SimaPro 8.2 and Ecoinvent 3.2 Software	1 Kg	From the farm door to the processor door	Energy consumption, climate change, water consumption.
LIFE CYCLE ASSESSMENT OF A MILK PROTEIN FRACTIONATION PROCESS: CONTRIBUTION OF THE PRODUCTION AND CLEANING STEPS AT UNIT PROCESS LEVEL	G.Gésan-Guizioua, A.P.Sobańtkaa, S.Omontb, D.Froelichb, M.Rabiller-Baudryc, F.Thueuxd, D.Beudone,L.Tregretf, C.Busong & D.Auffre	2019	France	MILK PROTEIN	Software SD2P®, SimaPro 8.0 y Ecoinvent V3.0	583 m3	From door to door	Global warming, water depletion, metals, energy use, acidification, terrestrial, freshwater, and human ecotoxicity
EFFICIENT USE OF WATER FROM IRISH DAIRY PROCESSING	M.-J. Yan & N. M. Holden	2019	Ireland	BUTTER AND POWDERED MILK	SimaPro 8.2 Software (PRé Consultores, 2019)	1 Kg	From the farm door to the processor door	Water use, eutrophication, global warming and acidification.
ENVIRONMENTAL LIFE CYCLE ASSESSMENT OF DAIRY PRODUCTS	Fehmi Gallant Triangle	2018	Turkey	*BUTTER, CHEESE AND MILK	*Software Ginebra	1 Kg	*From door to door	Global warming potential, acidification, eutrophication potential, photochemical oxidants, formation potential, ozone depletion, toxicity potential human potential, mineral use, land occupation, resource depletion, human health.

Therefore, it is recommended that the authors attempt to select a broader set of relevant impact categories, a selection that should be connected to the main environmental gains and losses that could be expected to be associated with the system studied.

In addition, authors generally need to be more specific in their choice of impact categories and in defining which characterization methods have been used to greatly improve the transparency of studies. Also, when using data/results from others, it is important to clearly show the characteristics, as the outsourcing methods used, especially when combining different data, can be confusing.

5. Conclusion

In this work, a review of studies was carried out in which the potential environmental impacts generated in the dairy sector have been examined, through the application of the Life Cycle Analysis (LCA) methodology.

The main findings were 42 publications of which 37 are peer-reviewed, 3 are scenario analysis and 2 are research directions.

The analysis of the sample provided an overview of the distribution of studies over time, considering the years 2015-2019, clearly showing a high concentration of studies in 2016; the continents that lead and group the most research on the subject of stroke were Europe with 20 studies out of 42 and America with 11 out of 42.

The studies were divided into 3 categories, the first was the LCA methodology applied to cheese production, the second was LCA applied to milk and the third was LCA applied to milk co-products.

Thus, in the analysis of dairy products, the following products were considered: fresh cheese, mozzarella, asiago, franxon, pecorino and padano, raw and processed milk (UHT and pasteurized), and co-products such as butter, powdered milk, whey protein concentrate, milk concentrate, and fermented whey.

The most studied dairy product life cycle was raw and processed milk, with 25 out of 42 studies, followed by cheese studies with 11 out of 42, and finally other types of dairy products with 6 out of 42.

Likewise, the most calculated impacts were eutrophication, followed by acidification and later climate change with 24, 23, and 22 of 42 studies respectively.

For each of these environmental impact categories, raw milk production was consistently found to be the most significant contributor to the total impact in grams, also regardless of product type, raw milk production emerged as the scenario with the largest contribution to the global environmental footprint. Therefore, many authors made several recommendations in the reviewed documents regarding how to reduce the environmental footprint of the dairy industry.

More than half of these recommendations were about production processes. Using more energy-efficient equipment and implementing renewable energy sources, such as photovoltaics, was a common indication.

Likewise, another suggestion was to optimize transportation routes and/or purchase local raw materials since, despite the relatively low contribution of the stage, it is influenced by portability to various environmental impacts, up to the cultivation stage.

Thus, the contributions of the different stages (raw milk production, factory processes, storage, use of transport, and waste treatment) have been investigated. for many impacts.

Thus, for products with relatively low energy intensity, such as raw milk, but with high use of fertilizers and agricultural material, on-site emissions were the main drivers associated with impacts such as land use, global warming potential, acidification, eutrophication, ecotoxicity, and water depletion.

Participation in the production processes in the plant. For impacts such as energy use, abiotic resource depletion, or photochemical ozone formation it was closer to that of mozzarella cheese production.

It was also found that ozone depletion is the only impact for which transport has a considerable effect and that steps such as water treatment or storage have negligible contributions to the environmental footprint, which are present in the production of fresh cheese and Franxón.

On the other hand, butter appeared as the dairy product with the largest environmental footprint, per unit of mass, followed by cheese. The reason for the high environmental footprint of this product was related to the high amounts of milk intake.

The most common recommendations for reducing the environmental footprint of dairy products were as follows: using more energy-efficient equipment for production, optimizing transport routes and using greener vehicles, modifying the feed content for the animal farm, and using renewable energy sources.

Based on the literature, there is a suggestion that fresh cheese has less environmental impact than semi-hard cheeses, especially when examining direct foods that consume less energy. However, given that in the cheese category only 5 studies out of 11 examined fresh cheese, there must be more case studies investigated to justify this claim, but these studies were found to be very complete and could in the future be of similar scale and accuracy to accurately estimate the true environmental impact of cheese production.

In this way, the reviewed literature also showed opportunities to simultaneously improve some processes of dairy production and minimize their associated costs.

The evaluation of the work also showed a gap in social and economic research lines, where it visibly demonstrated key metrics of social performance that are necessary to provide opportunities in the industrial development of some countries. On the other hand, in the economic area, the full potential of improvement alternatives must be explored to ensure a profit margin of cost savings for companies and at the same time offer sustainable value for the customer.

The findings were synthesized into an overall framework that facilitated an understanding of applications, potential improvements, and fields to explore regarding the implementation of Life Cycle Analysis in the dairy sector.

In the framework, information was valuable organized, and key points were clarified. Finally, the selection of the most appropriate element or combination of instruments for the specific stages of the Life Cycle Analysis was guided and facilitated.

Finally, the review identified gaps in the literature that can hopefully serve as inspiration for future studies. It is considered that this article will be very useful for all stakeholders in the agri-food sector and especially the decision of manufacturers who want to get an idea about the current state of the dairy industry from an environmental point of view.

This will serve as a reference point for further stroke studies. In addition, this study established a discussion on existing weaknesses and gaps in knowledge, along with recommendations to be able to carry out important research topics in the future.

Thus, LCA is framed as an important tool to make the process of knowledge of environmental impacts more transparent and to improve the production process, working to eliminate some waste and integrate it into the circular economy of the same company, as an efficient practice tool to seek sustainable values, not only for social and economic purposes but also for environmental purposes.

As it is one of the main techniques for environmental metrics and it will potentially become a powerful strategic management and decision-making tool to make society more sustainable and efficient in the use of natural resources

Finally, this analysis concludes with a clear idea that LCA is a very useful methodology with which its application can lead to major environmental changes since sustainability foresees the generation of value for human beings, perceived as a wider potential customer.

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