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LCI METHODOLOGY AND DATABASES

A critical evaluation of Brazilian life cycle assessment studies

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Abstract
Purpose A critical evaluation of the life cycle assessment (LCA) studies was performed in the main scientific bibliographic databases (online and free access) of Brazil where the LCA methodology could be considered.
Methods This has been an exploratory study with a qualitative evaluation of quantitative LCA studies with regard to International Organization of Standardization (ISO) 14040 standards. Firstly, the selected papers were those which used the LCA methodology in case studies (quantitative LCA studies). This survey was based on previously chosen keywords which were directly and/or indirectly related to LCA in Portuguese, English, and Spanish.
Results and discussion One hundred and twenty papers related to LCA were found, among which 21 have been effectively used the LCA methodology applied to case studies. The study has indicated agriculture and livestock as some promising areas for the use of LCA methodology in Brazil. As for the scope of LCA, it has been found that nine papers have adopted the cradle-to-grave approach, whereas 12 papers have limited the study to some life cycle stage (cradle-to-gate, gate-to-gate, or gate-to-grave). This behavior can be justified by the difficulty in obtaining data from raw material, supply chain, inputs, or about the disposal, reuse, and recycling of products/systems. The criteria set out in the ISO 14040 standard was carried out in 17 out of the 21 selected papers.
Conclusions The LCA of Brazilian studies could be improved. For instance, when considering the requirements and guidelines of ISO standards, at the goal phase, the papers have clearly mentioned their target audience. The scope phase requires more explanation about the allocation procedures, once the process/product is not isolated, and for most processes, it may generate more than one product. As regards the Life Cycle Inventory, these studies could improve their data sources, once few papers used primary sources. According to our understanding, the best phase performed by the papers was life cycle impact assessment. Hopefully, LCA will become a known research area and will be adopted by most of the Brazilian scientific community. It is further expected that LCA might have a regular publication in scientific journals (perhaps an own journal).

Keywords Bibliographical research · Brazilian case studies · ISO 14040 · LCA in Brazil · LCA studies

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1 Introduction

Life cycle assessment (LCA) has been largely accepted as a useful method to quantify and evaluate environmental interferences on life cycle processes and/or products (Willers et al. 2012). It majorly stemmed from the industry that demanded the development of new approaches and management tools to evaluate the environmental impacts from its activities. Therefore, since LCA has emerged in the 1960s, it has been mainly used by industries, research institutes, and universities.

In fact, LCA has been widely used and has contributed to consolidate the methodology around the world. However, differences on its development should be considered, since many countries still do not have the know-how to apply it to their environmental policies.

In South America, specifically in Brazil, the history of LCA began in the 1990s. The Brazilian Association of Technical Standards (*Associação Brasileira de Normas Técnicas*) has established the LCA subcommittee and thus integrated the International Organization of Standardization (ISO) Technical Committee 207 and the Support Group for Environmental Standardization (GANA) (Chehebe 1997; Santos 2006). In 1997, the first Brazilian book to address LCA—entitled *Análise do Ciclo de Vida de Produtos: Ferramenta Gerencial da ISO 14040*—was published by José B. Ribamar Chehebe. From 1997 to 1999, the first Brazilian LCA study, named *Análise do Ciclo de Vida de embalagens para o mercado brasileiro*, has been drafted; it was a LCA of packaging systems for the Brazilian market. This study was carried out by *Centro de Tecnologia de Embalagem* (CETEA), a specialized center for packaging technology from the renowned Brazilian Institute of Food Technology (CETEA 2011; Chehebe 1997; Lima 2007).

Since 2002, a group has been developing the Brazilian Life Cycle Inventory (Lima 2007). This project is an initiative of Brazilian Institute of Science and Technology Information (*Instituto Brasileiro de Informação em Ciência e Tecnologia* (IBICT)), in partnership with the University of Brasília, University of São Paulo (USP), and Federal Technological University of Paraná. The IBICT currently publishes on its website two Brazilian inventories related to important economic sectors: the Brazilian Inventory of Diesel and the Inventory of Refinery Products (Paulinia refinery (REPLAN)).

Also in 2002, the Brazilian Association of Life Cycle (*Associação Brasileira de Ciclo de Vida* (ABCV)), whose main goal was to disseminate and consolidate the concept of Life Cycle Management in Brazil, was founded. Accordingly, ABCV has promoted important conferences about LCA in Brazil, such as the second edition of the international conference on life cycle assessment in Latin America, which was held in São Paulo in 2007. In 2008, 2010, and 2012, ABCV has supported the Brazilian Congress on Life Cycle Management (CBGCV), consolidating its status as the major LCA conference in Brazil. Nonetheless, the papers published in such conference were not necessarily focused on quantitative LCA analysis.

In 2010, the life cycle assessment Brazilian program was created by the National Council of Metrology, Standardization and Industrial Quality (*Conselho Nacional de Metrologia, Normalização e Qualidade Industrial*). The main objectives of the program were as follows: to deploy of an internationally recognized system which can organize, store, and disseminate standardized information about Life Cycle Inventories of industrial production in the country; to prepare base inventories of the Brazilian industry; and to identify the main environmental impact categories in Brazil.

Despite the recent development of LCA studies in Brazil, the organization and structure of the methodology are noteworthy. Due to its diversity, the country offers many possibilities for the application of this methodology in both industrial and agro-industrial sectors, which are concerned about environmental impacts. In addition, academic institutions offer opportunities for researches, while supporting the development of new processes and products endowed with better environmental performance. Indeed, the academic area is of great importance, since it is responsible for developing studies intended to find solutions to environmental impacts caused by the industry and the agro-industry.

Whereas the results of academic studies are preferably published in scientific journals and conferences, this study was focused on identifying the development of LCA studies in Brazil. These studies were evaluated according to the main areas of application for LCA, as well as the methodology used by them.

2 Focus and definition of bibliographic databases

This study was focused on the major free access scientific Brazilian bibliographic databases wherein the LCA methodology could be considered. As Brazil does not have a specific journal or a permanent conference about LCA (despite the recently cited CBGCV), the major national conferences and journals recognized by the Brazilian Association of Production Engineering (ABEPRO) have been deemed appropriate. This association represents professors, researchers, students, and professionals from the Brazilian Production Engineering and comprehends ten major fields of knowledge and its respective subfields. Sustainable engineering is one of the subfields to which LCA thematic is included. Against this background, the used databases were as follows:

- Proceedings of the Production Engineering National Meeting—*Encontro Nacional de Engenharia de Produção* (ENEGEP)—from 1996 to 2010, available at http://publicacoes.abepro.org.br/. ENEGEP is promoted by ABEPRO and is recognized as the main conference of production engineering in Brazil.
- Proceedings of the Production Engineering Symposium—*Simpósio de Engenharia de Produção* (SIMPEP)—from 1999 to 2010, available at http://www.simpep.feb.unesp.br/anais.php. According to ABEPRO, SIMPEP became the second most important production engineering conference in Brazil in the past decade.
- *Produção Online Journal* (*Revista Produção Online*), ISSN 1676-1901, from 2008 to 2011, available at http://producaoonline.org.br/index.php/rpo/search. *Produção Online Journal* is associated with ABEPRO and

publishes papers related to production engineering including the environmental management field.
- *Brazilian Journal of Operations & Production Management* (BJO&PM), ISSN 1679-8171, from 2004 to 2011, available at http://www.abepro.org.br/bjopm/index.php/bjopm/index. It is associated with ABEPRO and publishers of the leading edge management systems of operation and production in academic institutions or industries.
- *Gestão Industrial Journal* (*Revista Gestão Industrial*), ISSN 1808-0448, from 2005 to 2011, available at http://www.pg.utfpr.edu.br/depog/periodicos/index.php/revistagi/search. This journal was certified from 2010 to 2012 with the ABEPRO stamp, an important recognition for scientific journals in the sphere of production engineering.
- Scientific Electronic Library Online (SciELO) Brazil database, covering articles published until June 2011, available at http://www.scielo.br/?lng=pt. In fact, SciELO is an acronym of Scientific Electronic Library Online; therefore, it is not a journal, but an electronic library covering a selected collection of Brazilian scientific journals. SciELO Brazil database was considered in this study, as it contains a wide range of official papers in the sphere of production engineering and environmental engineering journals wherein LCA could be applied. Because of its research tool, the website of SciELO Brazil provides an extensive database that goes beyond production and/or environmental engineering.

The CBGCV was not considered here, as its first and third editions proceedings are not freely available on the web.

3 Methodology

It was an exploratory study with a qualitative evaluation of quantitative LCA studies with regard to ISO 14040 standards. Firstly, we have selected the papers which adopted the LCA methodology in their case studies (quantitative LCA studies). The research was based on previously chosen keywords which were directly and/or indirectly related to LCA in Portuguese, English, and Spanish. The keywords were the following: life cycle, "ACV," LCA, "ciclo de vida," ISO 14040, ecodesign, "P + L," clean production, "produção mais limpa," "producción más limpia," and "produção limpa."

This study can be regarded as exploratory because it was performed with a view to developing, clarifying, and modifying concepts and ideas. By targeting the characteristics of the object or phenomenon under study or by establishing relationships between the variables, it may be also regarded as descriptive. Secondly, the study has selected the papers that truly adopted the LCA methodology in case studies. Then, this was also a qualitative study, once it has addressed the quality of LCA studies and their methodologies according to ISO 14040 standards, as well other characteristics.

The research has only included those papers available in the researched online databases, since access to the previously printed documents was not allowed.

4 Results and discussion

The bibliographic search has found 120 papers containing some citations related to life cycle assessment (LCA). Then, 21 papers which have effectively used the LCA methodology in case studies have been selected. In other words, these papers performed a quantitative LCA study. A total of 11 papers from ENEGEP, 4 from SIMPEP, 1 from *Produção Online Journal*, and 5 from SciELO Brazil have been selected (Table 1).

According to Table 1, most papers (about 52 %) are from the ENEGEP conference, followed by SciELO Brazil (24 %), the SIMPEP conference (19 %), and *Produção Online Journal* (5 %). Results show that ENEGEP is the preferred conference for publishing works related to LCA. Table 1 also shows important characteristics that allow drawing a scenario about LCA studies in Brazil, such as areas or issues related to application of LCA, methodologies, the scope of case studies, and software used in the LCA case study.

The IBICT has on its website a list of PhD and Master's theses as well articles related to LCA. By evaluating only the articles published on its site, it has been observed that most of them could be found in the SciELO database and ABEPRO conferences proceedings (except those published in internationals journals), as an example, the studies developed by Queiroz and Garcia (2010), Graf and Figueiredo (1999), and Giannetti et al. (2008). This reinforces the choice for free access databases from the main Brazilian conferences and journals of production engineering area.

The IBICT also recommends some LCA-specialized international journals such as the *Journal of Cleaner Production*, the *International Journal of Life Cycle Assessment*, and the *New International LCA Journal*. Because of their relevance to the international community, these journals are preferred by world researchers, including Brazilians (i.e., Ometto et al. 2009; Alves et al. 2010; Tanimoto et al. 2010; Rousset et al. 2011; Figueirêdo et al. 2012; Soares et al. 2013) who have been regularly publishing their works. Despite their relevance, the papers published in these journals were not considered in this study due the scope of our research.

4.1 Study areas and LCA application

In the selected papers, this topic was aimed at identifying the main areas in which the LCA was applied. These areas were related to the agro-industry (article numbers 1, 7, 11, 19, and 21; Table 1) and the production process of the pharmaceutical

Table 1 Papers that performed a quantitative LCA study

No.	Subject addressed	Authors	Conference or journal	Partnership institutions	Language
1	LCA of lettuce, comparison between conventional, organic, and hydroponic production	Graf and Figueiredo (1999)	ENEGEP	Universidade Metodista de Piracicaba (UNIMEP)	Portuguese
2	Comparative LCA of stainless steel sheet and carbon steel	Ferreira and Frank (2000)	ENEGEP	Universidade Regional de Blumenau (FURB)	Portuguese
3	Comparative LCA in the production process of knitted fabrics	Bastos and Possamai (2002)	ENEGEP	FURB; Universidade Federal de Santa Catarina	Portuguese
4	Simplified LCA applied to the evolution of lathes	Jacovelli and Figueiredo (2003)	ENEGEP	UNIMEP	Portuguese
5	LCA of oil refining process	Ugaya and Henschel (2004)	ENEGEP	Centro Federal de Educação Tecnológica do Paraná	Portuguese
6	LCA of plastic bags	Ibrahim et al. (2007)	ENEGEP	Centro Federal de Educação Tecnológica do Rio de Janeiro (CEFET-RJ); Universidade Federal do Rio de Janeiro (UFRJ)	Portuguese
7	LCA of poultry processing industry	Almeida et al. (2008)	ENEGEP	Universidade de Passo Fundo	Portuguese
8	LCA of transport of plastic covers used in electronic devices	Silva (2009)	ENEGEP	Instituto Nokia de Tecnologia	English
9	LCA of Portland cement	Nigri et al. (2009)	ENEGEP	Universidade Federal de Minas Gerais (UFMG)	Portuguese
10	Life Cycle Inventory and analysis in pharmaceutical production	Nunes et al. (2010)	ENEGEP	CEFET-RJ; Universidade Federal Fluminense	Portuguese
11	Simplified LCA of artisanal and industrial cachaça production	Nigri et al. (2010)	ENEGEP	UFMG	Portuguese
12	LCA of evaporators for sugarcane plants	Santos and Tenório (2010)	SciELO Brazil: Revista Escola Minas	USP	Portuguese
13	LCA of propylene glycol production	Bauer and Filho (2004)	SciELO Brazil: Brazilian Journal of Chemical Engineering	Pontifícia Universidade Católica do Rio Grande do Sul; Universidade Estadual de Campinas	English
14	Life cycle inventory of dental syringes manufacture	Giannetti et al. (2008)	SciELO Brazil: Revista Produção	Universidade Paulista	Portuguese
15	Recycling of polyethylene plastic bags in terms of Life Cycle Inventory	Queiroz and Garcia (2010)	SciELO Brazil: Revista Polímeros	CETEA/Instituto de Tecnologia de Alimentos	Portuguese
16	LCA of enameled porcelain	Hansen et al. (2010)	Revista Produção Online	Centro Universitário SENAC	Portuguese
17	LCA applied to the line of commercial vehicle painting	Goergen and Doki (2001)	SIMPEP	Debis Humaitá IT Services Latin America Ltda	Portuguese
18	LCA of board produced from cellulose manufacture-related waste	Santos et al. (2007)	SIMPEP	Universidade Estadual de São Paulo	Portuguese
19	LCA in a fishing area, for comparison of artisanal and industrial fisheries	Souza et al. (2008)	SIMPEP	UFRJ; Universidade Federal de São João Del Rei	Portuguese
20	LCA to identify the environmental impacts of composite materials made of glass and jute fibers, produced via RTM process	Silva et al. (2009)	SIMPEP	Instituto Superior Técnico, Portugal; Universidade Estadual do Sudoeste da Bahia	English
21	LCA of greenhouse gases emission in the life cycle of ethanol	Garcia and Von Sperling (2010)	SciELO Brazil: Revista Engenharia Sanitária Ambiental	UFMG	Portuguese

industry (article numbers 10, 13, and 14; Table 1), each one with four papers. Other important areas were the following: the plastic manufacturing industry (article numbers 6 and 15; Table 1), composite materials (article numbers 18 and 20; Table 1), and material types (article numbers 2 and 12; Table 1), each one with two papers. The remaining papers were related to metallurgy (article number 4; Table 1), oil refining process (article number 5; Table 1), cement production (article number 9; Table 1), automotive industry (article number 17; Table 1), ceramic industry (article number 16; Table 1), logistics (article number 8; Table 1), and knit fabric manufacturing (article number 3, in Table 1), each one with one paper.

Most papers (16 in 21, 76.2 %) were related to industrial applications, where only five were related to the agro-industry. This can be understood as a great opportunity for the development of LCA studies. In effect, Brazil is widely recognized as one of the major agro-industrial producers of grains livestock, and poultry. Furthermore, the Brazilian agribusiness system has a nonstandardized production comprehended by small subsistence farms deprived of techniques or large farms with cutting-edge technologies. This characteristic contributes to performing comparative LCA studies (Junqueira et al. 2008), and the results of which could contribute to achieve better environmental performance.

It has been observed that the selected papers were published over the last 11 years, whereas the former papers were published in 1999. During that period, no articles addressing LCA case studies in 2005 and 2006 were found (Fig. 1). There is a growing trend of articles about LCA case studies dating from 2007, especially from 2010. In that year, the published works increased about 200 %.

4.2 Methodology and scope of case studies

This section is related to the methodologies adopted in each LCA case study and the employment of computational tools to support the development of the study.

Seventeen in the selected papers have explicitly adopted the ISO 14040 standard in the analysis methodology. The other four papers have not explicitly followed the ISO 14040 standard (article numbers 1, 3, 19, and 21; Table 1), whereas the latter has adopted a methodology that comprehended important references and software that contained the cited ISO standard. Hence, it has been verified that 20 papers have directly or indirectly followed the ISO 14040 standards. Only one (article number 4; Table 1) paper has followed a semiquantitative method that used arrays to obtain a simplified LCA (Graedel et al. 1995).

A comparative LCA was performed in ten of the selected papers so as to determine the best option for similar goods or services (article numbers 1–4, 8, 11, 12, and 18–20; Table 1). Thus, different priorities were established in order to support the decision-making process, thereby fulfilling one of the goals of the environmental management tool.

The scope of case studies, in turn, was classified as follows: (1) "cradle-to-grave," in which the LCA included the entire product life cycle; (2) "cradle-to-gate," which eliminates the latter stages of the product manufacturing process; (3) "gate-to-grave," which eliminates the earlier stages of the product manufacturing processes; and (4) "gate-to-gate," which only covers the manufacturing stage (Almeida 2002). Hence, as a result of the scope, the papers presented in Table 1 are distributed as follows:

- Nine papers cradle-to-grave (article numbers 1, 2, 4, 8, 9, 14, 15, 18, and 19);
- Seven papers gate-to-gate (article numbers 3, 6, 7, 10, 13, 17, and 20);
- Four papers cradle-to-gate (article numbers 5, 12, 16, and 21) and;
- One paper gate-to-grave (article number 11).

Papers identified as cradle-to-grave have truly defined the environmental performance of the product, covering all stages of their life cycle. The cradle-to-grave, on the other hand, provides a better understanding of critical points and enables the identification of methods to improve environmental aspects. The gate-to-gate is focused on business aspects, as it includes the production process; in addition, it enables managers to understand environmental aspects, with the possibility to promote environmental strategies. However, such actions are restricted to

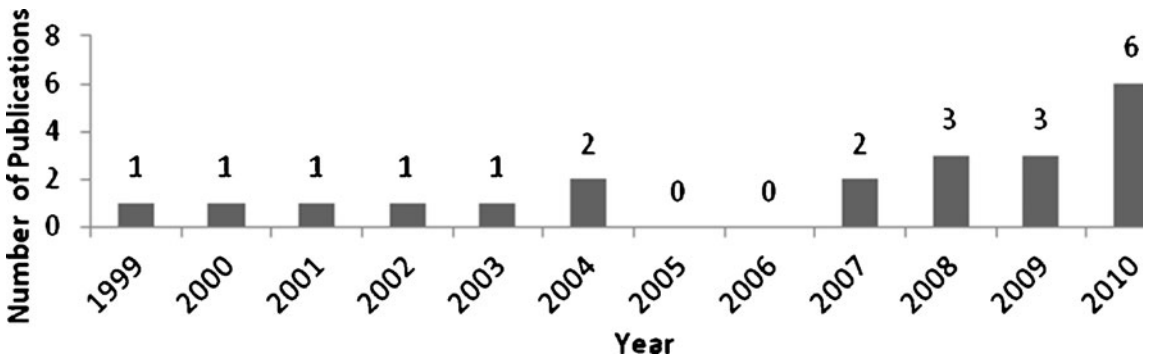

Fig. 1 Annual publication of articles addressing quantitative LCA studies

production processes, excluding another relevant phase of the life cycle.

When considering the use of software in LCA, 10 papers have used a software (article numbers 5–7, 10, 13, 15–17, 19, and 20, in Table 1), and 11 papers have not use a software (article numbers 1–4, 8, 9, 11, 12, 14, 18, and 21, in Table 1).

Accordingly, a few studies have not used any software to perform the LCA. It can be explained by the ISO 14040 standard (International Organization for Standardization (ISO) 14040 2006), which does not require, specify, or indicate the need of any software to perform LCA. Yet, the use of software to support the LCA study is useful to obtain detailed results, since it facilitates the management of data required to perform the life cycle inventory. Also, the use of software may reduce the time spent by LCA analysis while ensuring more reliable outputs.

Nevertheless, in order to define the real environmental impacts of products and/or systems on their entire life cycles, it is important to have a local database. This is one of the major difficulties to perform a LCA with the use of software in Brazil, since the Brazilian database is almost nonexistent. This is the reason why Brazilian studies use foreign databases (Rodrigues et al. 2008). This study did not evaluate the performance of the software, once this was out of its scope.

Based on the requirements and guidelines of ISO standard, a criterion was established to evaluate the LCA case studies assigned by this research (Table 2). Thus, three categories (unambiguously stated, stated but unclear, and not defined/performed) were defined according to Lu et al. (2009).

4.2.1 Goal

The ISO 14040 standard defines that the goal phase should present the intended applications and the targeted audience. Then, 13 out of 21 papers have defined their intended applications and were thereby classified as "unambiguously stated." Only two papers have clearly declared their target audience, whereas most of the others were seen to have neglected these criteria (14 papers). Both goal and scope phases are of great importance, since they support and limit the boundary conditions of the analysis. When this stage is neglected, important details are omitted and/or not considered, and even the level of detail for decision makers is compromised.

4.2.2 Scope

The scope considers different factors, such as functional unit, system boundary, rationale (including the criteria used to establish the system boundary), and allocation procedures. Because the functional unit provides references to input–output data, it should be clearly described. Thus, the functional unit must be measurable. However, it has been observed that 6 out of 21 selected papers were assigned as "not defined/performed," and 2 papers, as "stated but unclear." Therefore, those studies have not provided the basic data needed for a LCA study and their interpretation.

Regarding the system boundary, only two papers were classified as "undefined/performed;" ten papers, as "stated but unclear;" and nine papers, as unambiguously stated. This category is important to establish the boundary conditions and detail levels of the study and thereby define the process units to be included.

The rationale approach is used to establish the system boundary and the limits of life cycle stages. Thus, ten papers were classified as not defined/performed, and only eight papers have clearly justified the need for further details in the decision-making stages. The articles did not contain explicit information about the allocation procedures which are extremely important as there was no isolated system and most processes may generate more than one product.

4.2.3 Life cycle inventory

The Life Cycle Inventory (LCI) encompasses the following aspects: time, geographic and technological inputs, data source, and data uncertainty related to the functional unit, thus improving the quality of the assessment. Regarding the coverage of data, it was seen that eight papers had it clearly defined, whereas the other papers were defined as stated but unclear or not defined/performed. The coverage of data is very relevant to characterize the system and thereby makes the study more representative.

In the category "sources," five papers have clearly used primary data, whereas five other papers have used secondary data. Primary data are the best sources, as they describe the real context of the analysis. Secondary data, in turn, require the reference definition, as they are based on analogous approaches.

The uncertainty and quality of the data assessments were not performed by any of the selected papers, whereas data relating to the functional unit were clearly accomplished in six papers. This stage determines the reference flux as a function of the goal and the boundary system. Thus, five papers were classified as stated but unclear, and ten papers, as not defined/performed.

4.2.4 Life cycle impact assessment and life cycle interpretation

In order to analyze the effects of environmental loads, the impact assessment can be either qualitative or quantitative. Based on the ISO 14040 standard, this process must consist of selection, classification, and characterization of impact categories. These data must be clearly presented and well structured so that they can be assessed using decision makers. In this regard, 13 of the selected papers have clearly

Table 2 Comparison of life cycle assessment studies selected in this research

ISO standards guidelines	Classified papers		
	Unambiguously stated	Stated but unclear	Not defined/performed
Goal			
Intended applications	13	6	2
Targeted audience	2	5	14
Scope			
Functional unit	13	2	6
System boundary	9	10	2
Rationale (including criteria used in establishing the system boundary and deleting/omitting life cycle stages)	8	3	10
Explicit allocation procedures	0	0	21
Life Cycle Inventory			
Time-related, geographical, and technological coverage	8	9	4
Sources of data			
Primary sources	5	8	8
Secondary sources	5	7	9
Uncertainty of data/information	0	0	21
Functional unit-related data	6	5	10
Data quality assessments	0	0	21
Life Cycle Impact Assessment			
Selection of impact categories, indicators, and characterization models	13	2	6
Assignment of LCI results (classification)	9	5	7
Calculation of category indicator results (characterization)	7	5	9
Life cycle interpretation			
Identification of important issues based on LCI or LCA results	14	3	4
Conclusion	14	6	1
Recommendation	6	6	9
Limitation	0	7	14

declared their impact categories, while two were dined as stated but unclear, and six, as not defined/performed. The assignment of LCI results (classification) was performed in nine papers. As for the Life Cycle Impact Assessment, only seven have declared the characterization of impacts. This situation hampers the reproducibility of studies.

As for the interpretation of LCA studies, most papers could identify the significant points related to high environmental burden and reached a conclusion about the best process/product in analysis. The interpretation stage interacts with the data inventory, whereas the impact assessment could be subjective or has only affected the results of personal preferences.

5 Conclusions

This study was aimed at establishing a critical evaluation about the life cycle assessment of Brazilian studies. The search for articles in the main Brazilian free access databases from production engineering was a good choice, since there were 120 papers that mentioned the LCA methodology over the past 15 years. In the 120 articles, 21 papers have used the LCA methodology for a case study and were found in the proceedings of ENEGEP (11 papers or 52 %) and SIMPEP (4 papers or 19 %), *Produção Online Journal* (1 paper or 5 %), and SciELO Brazil database (5 papers or 24 %). There was no evidence of articles from BJO&PM and *Gestão Industrial Journal*. It should be noted that 12 out of the 21 selected papers (57 %) were published over the last years (2008–2010), reflecting the current growing tendency of Brazilian LCA studies. Most papers were found in the conference database of ENEGEP. Excluding the international journals, our research allowed to find most of articles cited by the IBICT database, which is considered as a reference for the LCA Brazilian community. Hence, these bases can be considered as the main Brazilian online free access database related to LCA.

In effect, due to it multidisciplinary characteristic, LCA can be found in different areas of knowledge, such as Chemistry. However, apart from production engineering, it was difficult to find proceedings and even Brazilian journals

(except those from SciELO) with online free access. Despite this information, one can conclude that these databases are representative and comprehensive enough for such a study, once it contains one of the main ways for publishing scientific articles in Brazil, wherein the LCA thematic area can be included.

Another important focus identified in this study concerns some promising areas (agriculture and livestock) for the adoption of LCA methodology in Brazil. Indeed, there is a lack of studies related to these areas, which have great economic and social importance to the country and are feasible for the development of LCA studies.

As regards the scope of LCA, it has been found that 9 papers have adopted the cradle-to-grave approach, whereas 12 papers have limited the study to some life cycle stage (cradle-to-gate, gate-to-gate, or gate-to-grave). This can be justified by the difficulty in obtaining data from raw material, supply chain, inputs, or about the disposal, reuse, and recycling of products/systems.

The ISO 14040 standard (2006) was used in 17 out of the 21 selected papers. There was a predominance of studies (11 articles) that have not used any software to perform LCA, whereas ten papers have used some software. This is consistent with the methodology recommended by ISO 14040 standard (2006), which does not require, specify, or indicate a software to perform the LCA. Despite the usefulness of software in the LCA study, its use is not a constraint factor. Critical discussions on the specific software used in the studies are out of this article scope.

By comparing the LCA studies based on the ISO 14040 standard (2006), we have realized that the LCA of Brazilian studies could be improved. For instance, when considering the requirements and guidelines of ISO standard, at the goal phase, the papers have clearly mentioned their target audience. This important feature is determined by the choices made during the development of a LCA study. The scope phase requires more explanation about allocation procedures, once the process/product is not seen in an isolated manner and, also for most processes, may generate more than one product.

Concerning the LCI, it was found that the Brazilian studies could improve their data sources, once a few papers have used the primary sources. As Brazil does not have a variety of inventories, this represents an opportunity and should further contribute to the development of Brazilian inventories in different areas. This initiative could help consolidate the LCA methodology in Brazil. In the LCI as well, the selected papers did not perform the uncertainty and data quality assessments. These processes should have been performed, as this step directly interferes in the results and interpretation due to data uncertainty. According to our understanding, the Life Cycle Impact Assessment was the best phase performed by the papers; moreover, the ISO 14040 standard does not require the application of all steps. The last aspect to be considered was the life cycle interpretation, wherein it has been stressed that clear conclusions were drawn in most studies. Few papers have presented considerations about the recommendations and limitations.

Hopefully, LCA will become a known research area and will be adopted by most Brazilian researchers and institutes. It is further expected that LCA might have a regular publication in scientific journals (perhaps an own journal). It is believed that CBGCV will consolidate itself as the main Brazilian conference focused on LCA. Accordingly, it will be possible to develop a scientific database to be used as a reference for studies in Brazil.

Finally, this study aimed at addressing the LCA, seeking to contribute to the best dissemination of the methodology in Brazil.

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