A bibliometric contribution of the strategies of reverse logistics in waste electrical and electronic equipment (weee) management

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Abstract

In recent years, with the increasing of waste, the reverse logistics become an important strategy for meeting the necessaries of the society and work market. Among the huge amount of discard products are the waste electrical and electronic equipment (WEEE), which it has become a major problem for developing countries due to its harmful effects. This paper characterizes and analyses the bibliometric review of the reverse logistics strategies applied in Waste Electrical and Electronic Equipment (WEEE) Management. The methodological approach used is the systematic review of the literature, based on bibliometric theory, through consultation with the ISI Web bases of Science and Scopus, and their treatment by Excel and Mendeley software. For research was used "Reverse Logistics" and "WEEE" as an expressions key, generating a sample of 43 articles published. At the end of the study were presented descriptive analysis results with the identification of the years, authors, research source, countries and research methods, and a bibliometric analysis results by the number of citations.

Keywords: Waste Electrical and Electronic Equipment (WEEE), Reverse Logistics, Bibliometric Review.

1 Introduction

Nowadays, reverse logistics issues have become more and more important to strategies management due to environmental, social and economic reasons. Reverse logistics – RL is the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing value or of proper disposal (Tibben-Lembke and Rogers, 2002).

The operation activities of reverse logistics include collection, packaging, storage, sorting, transaction processing, delivery and integration, and/or correct disposal. According to (Caiado et al., 2017), the RL process uses the same activities of forward logistics, the difference lies in the moment that these activities start, from time that forward logistics ends.

In addition, it should be emphasized that reverse logistics is necessary for extending the life of materials, and plan and operationalize the return of products to logistics cycle. These aspects are considered critical to reducing environmental impacts of industrial operations, and solve the problem of scarcity of raw materials (González-Torre et al., 2010).

Some operations of logistics cycle needy an efficient reverse logistic network is necessary a product recovery, such as comprises recycling, remanufacturing, repairing and disposing. Among used products, waste electrical and electronic equipment (WEEE) has become a major problem for developing countries due to

its harmful effects. According to (Shokouhyar and Aalirezaei, 2017), WEEE contains hazardous materials that may have an impact on both environment and human health if it is properly managed.

Advances in technology have led to an exponential growth in waste electrical and electronic equipment. WEEE and its components, due to its risk and toxicity, require the correct equation of its parts, making the reverse logistics of these products subject of recent decrees and laws worldwide (de Oliveira et al., 2012; Wang et al., 2012). Therefore, the implementation of the reverse logistics of waste electrical and electronic equipment (WEEE) and its components has been a major concern for the government and the private sector.

From this perspective, the objective of this work is presents a bibliometric review of the reverse logistics strategies applied in Waste Electrical and Electronic Equipment (WEEE) Management. As a contribution, this paper served as base of scientific evidences in the study of the strategies of the reverse logistics applied in the WEEE, which it could be used in future works. The methodological approach used is the systematic review of the literature, based on bibliometric theory.

The articles in the sample were cataloged and analyzed annually, by authors, by research source, by country of origin, number of citations and distribution of reviewed papers by research method. In conclude, we aim to discover the distribution of the articles by their research methods, and the most used method was the qualitative method in 14 papers, followed by simulation, case study and system support decision. In addition, it was clear that exists a lack of researches doing literature reviews or surveys method.

This article is structured in five sections with this introduction. In the section 2, a theoretical background; in the section 3 the description of the methodology of the samples definition and the analysis techniques; in the section 4, the results; and in the section 5, the final considerations and suggestion for future research.

2 Background

Several works were developed involving reverse logistics and WEEE. In this scenario, we highlight four important papers that synthesizes our research.

First, (Shokouhyar and Aalirezaei, 2017) presented a sustainable recovery network for waste from electrical and electronic equipment using a genetic algorithm and aimed to developed a mathematical model of two-stage RL network based on sustainable development objectives in which economic, environmental and social objectives are considered simultaneously.

Then, (Cole et al., 2016) presented a study that outlines current policy context, explores routes for end-of-life EEE in the UK and examines opportunities for product life extension through reuse.

Then, (Agarwal et al., 2012), presented a PSO-based optimum consumer incentive policy for WEEE incorporating reliability of components and aimed to understand the consumer return behavior of end of life goods at different incentive levels and make an attempt to incorporate the latest research practices.

Finally, (Zhi et al., 2010) presented an Application of genetic algorithms for the design of WEEE, and aimed to formulate a mathematical model of remanufacturing system as two stage logistics networks in order to minimize the total recycle cost.

In order to elucidate the concepts of WEEE and reverse logistics, we present some definitions below.

2.1 Waste of eletrical and eletronic (WEEE)

Responsibility for waste generated from WEEE, once a concern only of environmentally friendly companies, has become mandatory for producers, distributors and consumers of these products. In addition, it can be noticed that the high consumption of the companies by these products increases every day, due to the large volumes of equipment purchased and the fast rate of obsolescence, which generates significant quantities of discards daily (Caiado et al., 2017; Cole et al., 2017).

The market value of electronic waste has been very attractive to managers and there is evidence of a possible future shortage of inputs used in the production of such equipment. Therefore, as a solution to

this problem, several companies observed a great opportunity present in the recycling of these products (Caiado et al., 2017; Cole et al., 2017).

In general, electrical and electronic products have several applications, among them, the most common are: printed circuit boards, electrical cables, display equipment, as screens, battery displays, capacitors, resistors and relays, sensors and connectors. The most dangerous substances, from the environmental point of view, these components are: heavy metals, such as mercury, lead, cadmium and chromium, the greenhouse gases, halogenated substances, such as chlorofluorocarbons (CFC), the polychlorinated biphenyls (PCB), the chloride polyvinyl chloride (CPC) and brominated flame retardants, as well as asbestos and arsenic 8 (Caiado et al., 2017; Cole et al., 2017).

2.2 Reverse logistics

According to (Tibben-Lembke and Rogers, 2002), and exposed by (Caiado et al., 2017) reverse logistics is the planning process, efficient implementation and control, of the economic flow of raw materials, process inventory, finished goods and related information from the point of consumption to the point of origin with the objective of recapturing value or proper disposal and reverse logistics operational activities include collection, packaging, storage, sorting, transaction processing, delivery integration and correct disposal.

Therefore, the reverse logistics process uses the same activities of conventional logistics, however, reverse logistics activities begin at the time when conventional logistics activities end. In this scenario, reverse logistics is committed to extending the life of materials and to plan the return of these products in the logistics cycle in order to reduce the environmental impacts of industrial operations and solve the problem of raw material shortages (Caiado et al., 2017; González-Torre et al., 2010).

3 Methodology

Bibliometric is a set of methods to quantitative analyze academic literature, which it was introduce by Pitchard in 1969. According to (Pilkington and Meredith, 2009), bibliometric is defined as the research technique that aims to analyze the size, growth and distribution of the bibliography in a given field of knowledge. The purpose of the bibliometric analysis is increase the performance of researches or evaluate their trends, investigating the characteristics of publications, such as authorship, research sources, themes, geographical origins, citations and cocitations (Endler et al., 2016).

Based on these concepts of bibliometric analysis and the aim of this work on presents a bibliometric review of the reverse logistics strategies applied in WEEE Management, this study was led by three steps for the development of the research, illustrated in Figure 1.

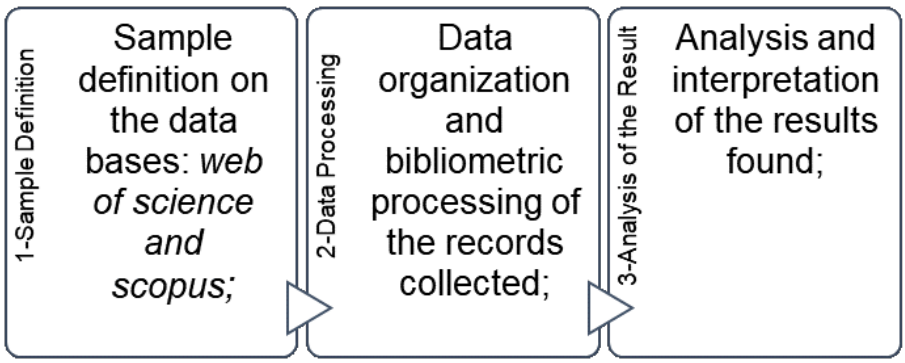

Figure 1: Research Processing. Adaptation of (Endler et al., 2016)

3.1 Sample definition

From the choice of the database, identification of keywords, sources of published documents, language and elimination of articles that were not relevant to the topic, it all were the definition of the journal samples about reverse logistics strategies applied in WEEE Management. After, we read the complete papers to evaluation them as illustrated in Figure 2.

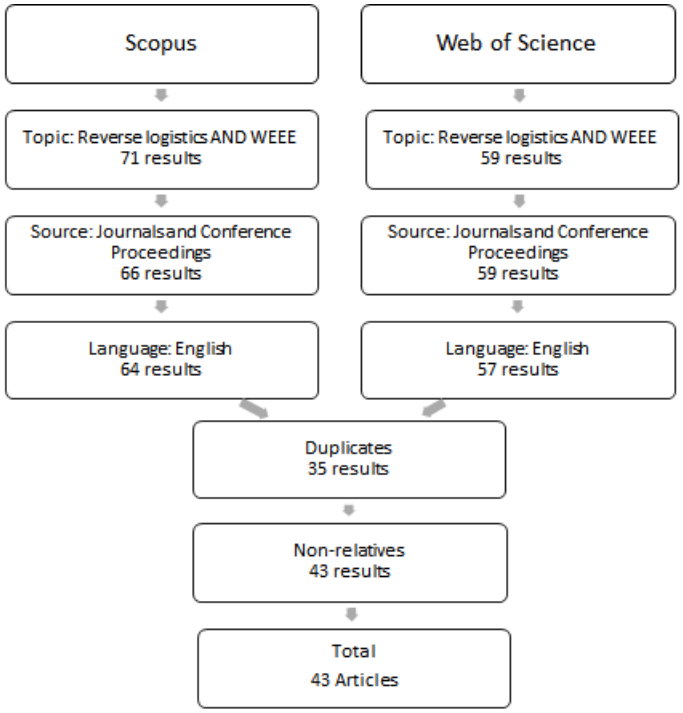

Figure 2: Flowchart of the sample definition process

We choose two databases to use in this work: Web of Science and Scopus, which the two of them contemplate most of the main journals on the subject studied. To identification of keywords, we used "reverse logistics" and "WEEE" that resulted on 71 articles from Scopus and 59 from web of science.

Regarding the determination of source of published documents, we choose just articles published on journals and conference proceedings. According to (Endler et al., 2016), in general, it is considered that articles resulting from these media are safe sources for research and present methodological rigor for publication. Therefore, at the end of these definitions, we had 66 articles from Scopus and 59 from Web of Science. In addition, we considered just articles published in English; as a result, we had 64 from Scopus and 57 from Web of Science.

Then, we excluded 35 duplicated articles in both databases. Therefore, the sample definition was concluded disregarding articles evaluated that were not relevant to the theme, by reading and evaluating the content. The exclusion criteria adopted were:

- Papers that is not about WEEE;
- Papers which do not discuss Reverse Logistics;
- Papers with focus on Operational Research Methods;
- Papers which discuss Costs Analysis.

Finally, 43 articles were analyzed with no restriction on the publication year, see Appendix A.

3.2 Data organization and bibliometric processing of the records collected

The 43 articles in the sample were cataloged and analyzed annually; by authors; by research source; by country of origin (Google Maps was used for its geographical representation), number of citations for each

databases and distribution of reviewed papers by research method.

Also, to organize the articles, we used Mendeley Software, a reference manager, which made it possible to perform the filtering of the papers, organizing by author, year, and others. In addition, we exported the information needed to a spreadsheet on Excel to plot the figures, graphs and tables. In the world map organization, we used a Google Maps tool to highlight the countries.

4 Result Analysis

In the first analysis, we show the tendencies of increasing or decreasing of the researches of the strategies of the reverse logistics applied in waste electrical and electronic equipment (WEEE). The Figure 3 shows how many publications were submitted year by year, starting in 1998 until 2017. The first paper was published by (Nagel, 1998) and the highest level was reached in 2016 with a total of 9 publication in that year.

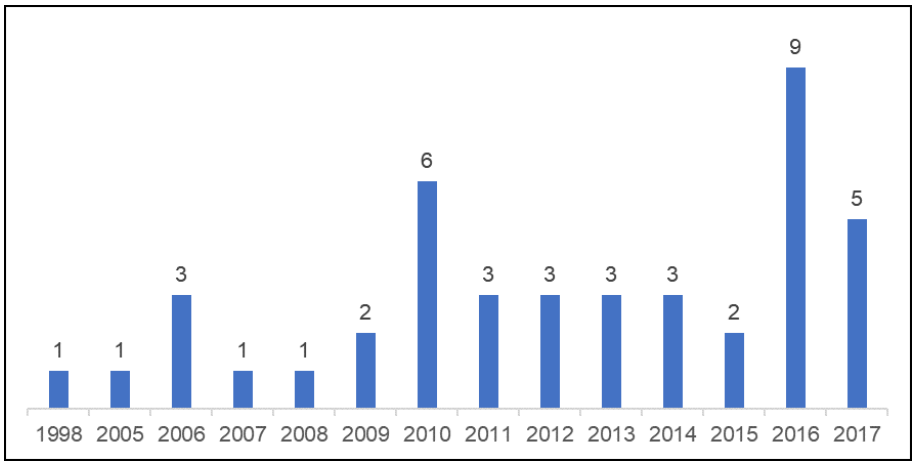

Figure 3: Number of publications by year

Furthermore, we made an analysis to identify the authors with more publications in this area. The results showed that exists an equal distribution among the authors. None of them published more than two articles about the scope proposed. In a total of 122 authors, 11 published 2 articles each, and the others only one article each, remembering that 43 articles were analyzed. In Figure 4, the distribution with the authors with more publications is presented.

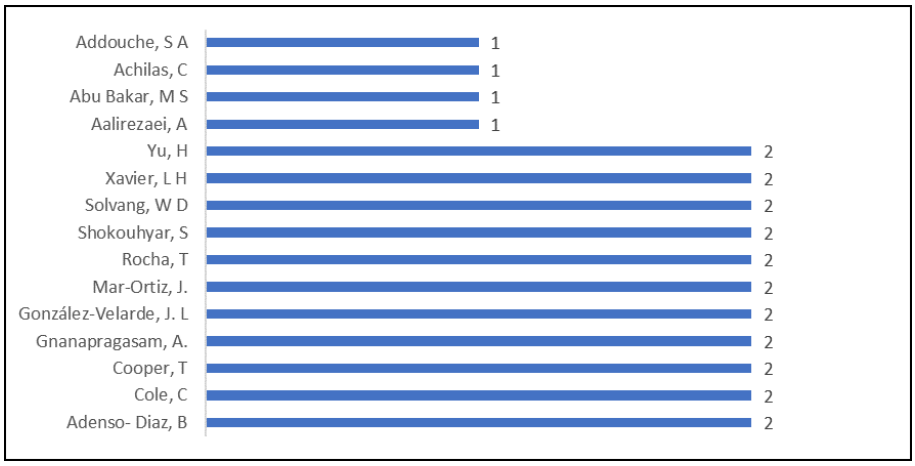

Figure 4: Number of publications by author

In relation with the distribution of the articles by source type, the highlight was the journal “Waste Management” with 3 papers published. Also, we observed that the 43 papers analyzed were published in 37

different journals and conference proceedings. Beyond the journal Waste Management" with 3 publications (Achillas et al., 2010; de Souza et al., 2016; Ghisolfi et al., 2017), 4 sources have 2 publications each, and the rest of them have 1 publications each. As we show in Figure 5, the top 8 journals and conference proceedings classified by number of publications

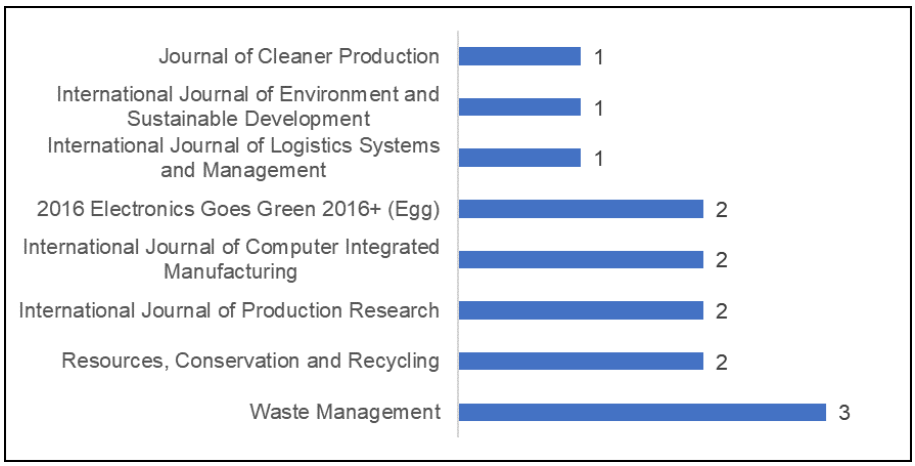

Figure 5: Number of publications by source type

In addition, we did a classification of the 43 papers by country, and we found that China and Brazil are predominant in publications in this area of research, with 7 and 6 papers, respectively. In Figure 6, we show the world map with all the countries with some publication highlighted.

Figure 6: World map of highlighted countries with publications

Also, in Figure 7, we show the quantity of articles published by country, but only the ones with at least 2 published papers.

Next, we looked to know which are the most cited papers. In Table 1, there are the top 10 most cited articles in both databases, Scopus and Web of Science, respectively. In fact, (Achillas et al., 2010) leads the list with a large difference in both databases from the other papers, with 64 and 55 times cited, respectively.

Additionally, the top 4 most cited (Achillas et al., 2010; Tsai and Hung, 2009; Krikke, 2011; Janse et al., 2010) from both databases are the same and in the same order, which means that they really are relevant on this area.

Finally, we aim to discover the distribution of the articles by their research methods. Reading the articles, we found that the most used method was the qualitative method in a total of 14 papers, followed by sim-

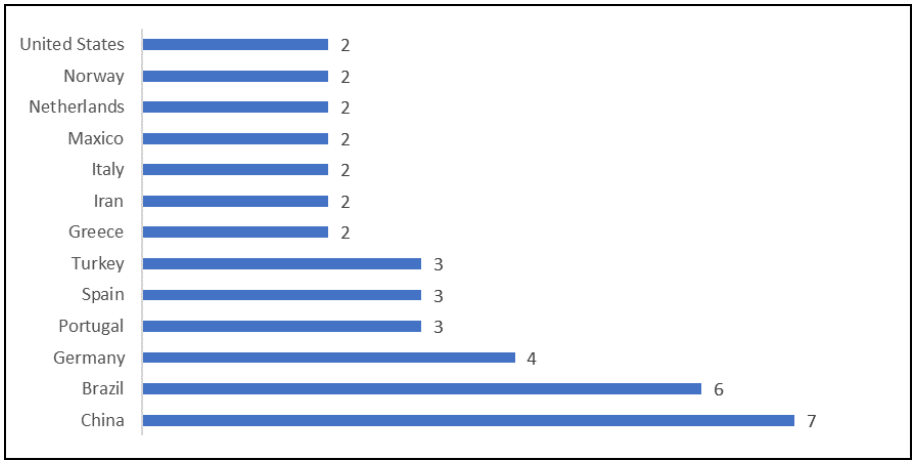

Figure 7: Number of publications by country

Table 1: Top 10 most cited articles on Scopus and Web of Science databases

Scopus		Web of Science	
Article	# of citations	Article	# of citations
(Achillas et al., 2010)	64	(Achillas et al., 2010)	55
(Tsai and Hung, 2009)	47	(Tsai and Hung, 2009)	37
(Krikke, 2011)	43	(Krikke, 2011)	33
(Janse et al., 2010)	29	(Janse et al., 2010)	18
(Guerra et al., 2009)	15	(Mar-Ortiz et al., 2011)	9
(Melacini et al., 2010)	13	(Liu et al., 2016)	7
(Liu et al., 2016)	11	(Agarwal et al., 2012)	6
(Mar-Ortiz et al., 2011)	10	(Cao et al., 2016)	5
(Agarwal et al., 2012)	9	(Capraz et al., 2015)	5
(Shokohyar and Mansour, 2013)	8	(Abu Bakar and Rahimifard, 2008)	5

ulation, case study and system support decision, in that order, Figure 8. Also, it was clear that exists a lack of researches doing literature reviews or surveys method.

5 Conclusion

Therefore, the study showed that the research of the strategies of the reverse logistics applied in waste electrical and electronic equipment (WEEE) has increasing in the past years. The boom occurred in 2016 with 9 articles, until the date of this study. Also, we discover that C. Nagel was the pioneer in that area, publishing his article in 1998, 19 years ago.

The number of authors that published in this area is kind large (122 authors, precisely), however none of them published more than 2 articles each. The same occurs with the journal and conference proceedings, only the journal “Waste Management” differed the others having 3 papers published.

Furthermore, China, Brazil and Germany stood out in relation of number of publications by country, with 7, 6 and 4 papers, respectively. In total of 22 countries, 9 of them had 1 published paper each only.

Moreover, the analysis by number of citations showed that C. Achillas is the principal reference in strategies of reverse logistics applied in WEEE. In both databases, Scopus and Web of Science, C. Achillas appeared on top of the most cited with his paper from 2010 named as “Decision support system for the optimal location of electrical and electronic waste treatment plants: A case study in Greece”.

Finally, in the results we observed that exists a lack in the research using classic methods such as literature review and surveys method. It shows a real opportunity for future researches, once those methods are non-explored nowadays. Also, another suggestion for future, it would be researches using other databases to

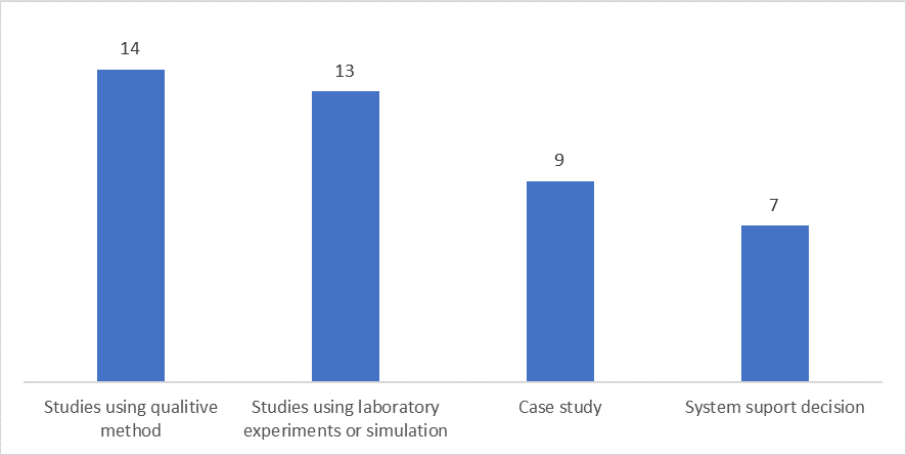

Figure 8: Number of publications by research method

cover more articles and authors. In addition, we suggest a more accurate descriptive analysis encompassing other tools, such as co-citation network, e.g.

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A Sample of the 43 articles analyzed

#	Author	Year	Reference
1	Nagel, Carsten	1998	(Nagel, 1998)
2	Knoth, R; Kopacek, B; Kopacek, P	2005	(Knoth et al., 2005)
3	Chang, X; Huo, J; Chen, S	2006	(Chang et al., 2006)
4	Fernandez, I; *et al*	2006	(Fernandez et al., 2006)
5	Zhang, H J; Huang, H W	2006	(Zhang and Huang, 2006)
6	Butz, C	2007	(Butz, 2007)
7	Abu Bakar, M S; Rahimifard, S	2008	(Abu Bakar and Rahimifard, 2008)
8	Guerra, L; Murino, T; Romano, E	2009	(Guerra et al., 2009)
9	Tsai, W.-H.; Hung, S.-J.	2009	(Tsai and Hung, 2009)
10	Achillas, C; *et al*	2010	(Achillas et al., 2010)
11	Janse, B; Schuur, P; De Brito, M P	2010	(Janse et al., 2010)
12	Liu, X; Qiu, J; Liu, M	2010	(Liu et al., 2010)
13	Machado, V H; *et al*	2010	(Machado et al., 2010)
14	Melacini, M; Salgaro, A; Brognoli, D	2010	(Melacini et al., 2010)
15	Zhi, G.-J.; Dong, X.-B.; Zhang, R.-X.	2010	(Zhi et al., 2010)
16	Krikke, Harold	2011	(Krikke, 2011)
17	Lei, L; Qu, L	2011	(Lei and Qu, 2011)
18	Mar-Ortiz, J; *et al*	2011	(Mar-Ortiz et al., 2011)
19	Agarwal, G; Barari, S; Tiwari, M K	2012	(Agarwal et al., 2012)
20	Mar-Ortiz, J; *et al*	2012	(Mar-Ortiz et al., 2012)
21	Sathaporn, M;Ruth, B	2012	(Sathaporn and Ruth, 2012)
22	Emmanouil, M C; *et al*	2013	(Emmanouil et al., 2013)
23	Shokohyar, S; Mansour, S	2013	(Shokohyar and Mansour, 2013)
24	Yu, H; Solvang, W D	2013	(Yu and Solvang, 2013)
25	De Mendonça, F M; *et al*	2014	(De Mendonça et al., 2014)
26	Tari, Işıl; Alumur, Sibel A	2014	(Tari and Alumur, 2014)
27	Tepe, S; *et al*	2014	(Tepe et al., 2014)
28	Capraz, O; Polat, O; Gungor, A	2015	(Capraz et al., 2015)
29	Correia, A J C; *et al*	2015	(De Jesus Cardoso Correia et al., 2015)
30	Cao, J; *et al*	2016	(Cao et al., 2016)
31	Cole, C; Cooper, T; Gnanapragasam, A	2016	(Cole et al., 2016)
32	de Souza, R G; *et al*	2016	(de Souza et al., 2016)
33	Dhib, S; *et al*	2016	(Dhib et al., 2016)
34	Falsafi, M; Fornasiero, R	2016	(Falsafi and Fornasiero, 2016)
35	Lima, A B; *et al*	2016	(Lima et al., 2016)
36	Liu, H; *et al*	2016	(Liu et al., 2016)
37	Qiang, S; Zhou, X.-Z.	2016	(Qiang and Zhou, 2016)
38	Yu, H; Solvang, W D	2016	(Yu and Solvang, 2016)
39	Caiado, N; *et al*	2017	(Caiado et al., 2017)
40	Cole, C; Gnanapragasam, A; Cooper, T	2017	(Cole et al., 2017)
41	Ghisolfi, V; *et al*	2017	(Ghisolfi et al., 2017)
42	Paes, C E; *et al*	2017	(Paes et al., 2017)
43	Shokouhyar, S; Aalirezaei, A	2017	(Shokouhyar and Aalirezaei, 2017)