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Review

Recycling Organic Fraction of Municipal Solid Waste: Systematic Literature Review and Bibliometric Analysis of Research Trends

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Abstract: The organic fraction is usually the predominant fraction in municipal solid waste, so its recycling is a potential alternative to disposal in landfill sites, as well as helping to reach targets included in the European Circular Economy Package. The existing body of knowledge in this research field is very large, so a comprehensive review of the existing scientific literature has been considered of interest to provide researchers and professionals with a detailed understanding of the status quo and predict the dynamic directions of this field. A systematic literature review and bibliometric analysis have been performed to provide objective criteria for evaluating the work carried out by researchers and a macroscopic overview of the existing body of knowledge in this field. The analysis of 452 scientific articles published from 1980 to 2019 has shown that the application of composting technologies is relevant, especially since 2014, when policies aimed at reducing emissions to the atmosphere were increased and focused on the use of this waste fraction to produce biogas. Nevertheless, the scientific field is still evolving to impose a model of a circular economy; in fact, emerging studies are being conducted on the production of biomethane, contributing to the decarbonised energy system.

Keywords: bibliometric analysis; analysis of science mapping; SciMAT; systematic literature review; municipal solid waste; organic fraction

1. Introduction

Municipal solid waste (MSW) management is an important challenge of the urban environment in most cities worldwide today. In fact, a big problem concerns the planning of treatment plants that can face the quantity and composition of municipal waste [1]; as a consequence, sustainable management solutions should be designed [2]. In this respect, several studies have reported that the composition of MSW varies significantly from one country, region or municipality to another, including food waste, metals, plastics, glass, textiles or inert materials, among others [3]. The composition of MSW depends significantly on factors such as lifestyle, economic level or legal framework, and knowledge of it is critical to determining the appropriate handling and management of these wastes [4,5]. However, the organic fraction (OFMSW) is usually the predominant fraction, in the case of its selective collection not being implemented; in fact, the percentage of the OFMSW worldwide is 46%, varying between 64% in developing countries and 28% in the case of higher-income ones [6]. Although the data indicate a slight reduction in the proportion of organic waste in 2025, it is forecast that solid waste generation rates will exceed 11 million metric tons per day, which is more than three times the current rate, for the year of 2100 [6]; given that the amount of organic waste will increase along with the total amount of solid waste [7], its recycling has attracted a great deal of attention as a potential alternative to the conventional solid waste disposal of a wide range of residues in landfill sites, mainly for the countries outside of the EU, where waste regulation is not so stringent.

Traditionally, the most commonly used technologies for the recycling of the OFMSW are composting and anaerobic digestion to produce compost and biogas and digestate, respectively [8–10]. Compost and digestate are rich in nutrients, so they are used as organic amendments in soils [11]; the methane content in biogas makes it a source of renewable energy [12]. These treatments are widely known and applied today; however, the search for systems that reduce some of the limits of aerobic digestion (for example, the problems of odours, occupation of space and degradation time) [7,13] or improve performance in terms of the production of methane [14,15] have led to technological development, for example, the co-composting of OFMSW and another organic solid waste such as faecal sludge [16,17] and animal and/or agricultural waste [18–20], among others, or the reaction of wet organic substrates under hydrothermal conditions or hydrothermal carbonisation (HTC) [21]

On the other hand, increasingly tight regulations, for example, Directive (EU) 2018/850 amending Directive 1999/31/EC on landfill waste, as well as the increasing demand for renewable fuels, are driving the conversion of the wastes into valuable bio-products that can substitute non-renewable materials and ensure the effective use of existing resources through circular flow loops in a sustainable way. In fact, the European Commission has recently adopted an ambitious Circular Economy Package, which includes measures to drive Europe's transition towards this economic model, which includes a common EU target for recycling 65% of municipal waste and reducing landfill to a maximum of 10% of municipal waste by 2030 [22]. To reach these targets, recycling technologies applied to the organic matter of municipal solid waste now represent an important strategy in the area of waste treatment; this may be perceived as a potential alternative to provide a renewable source of energy, as well as to use the recycling potential of the biodegradable fraction of waste generated by a large number of activities [23].

On account of the important current research to promote the recycling of OFMSW as well as the great diversity of applicable technologies, uses of by-products, construction and operation costs, social acceptance, environmental impacts or measures that promote the implementation of treatment systems for this fraction, it is difficult to obtain a single point from which to access this topic. This diversity also leads to a lack of a broad view of the area of research or the evolution of issues in this field, which makes it difficult to obtain useful and impartial information for future work. Therefore, developing a comprehensive review of the existing scientific literature has been considered of interest to make it easier to integrate the contributions in order to obtain a critical perspective.

In this sense, the bibliometric analysis provides objective criteria to evaluate the research carried out in a field [24], as well as a macroscopic overview of large amounts of scientific literature [25]. However bibliographic study dates back in a particular field to the 19th century; Alan Pritchard coined the concept of bibliometric analysis in 1969 [25]. This methodology has grown exponentially with the development of the internet, which has made easier and faster the communication between researchers, as well as the access to contributions in a given field around the world [26].

Performance analysis and science mapping are the two main methods of bibliometric research. The first one aims at the evaluation of the impact of citations in scientific production; on the other hand, science mapping defines the conceptual, social and intellectual scientific research structure, and its evolution. These methods show a representation of the relationships between the disciplines, fields, specialities, documents or authors [27]; they also examine the bibliographic material from an objective and quantitative perspective [28]. In consequence, many disciplines use these methods to study the impact of their field, researchers, or a particular document, in order to determine the structural and dynamic characteristics of scientific research [29].

The objective of this study was thus to develop a bibliometric analysis of the organic fraction of municipal solid waste recycling treatments, through the performance of (i) a systematic review for a quantitative analysis, (ii) a qualitative review using a science mapping study and (iii) the analysis of results.

This study will establish research themes, mapping researcher networks and recommendations for future studies in the research field of recycling OFMSW, contributing to the existing body of knowledge by assessing and highlighting the patterns and trends in the research field.

2. Materials and Methods

Figure 1 shows the double integrated analysis performed to achieve the objectives of this study, including: (i) a systematic literature review (SLR) of the bibliographic records on recycling the OFMSW, and (ii) a bibliometric analysis of the identified documents. The sections below describe each of these procedures.

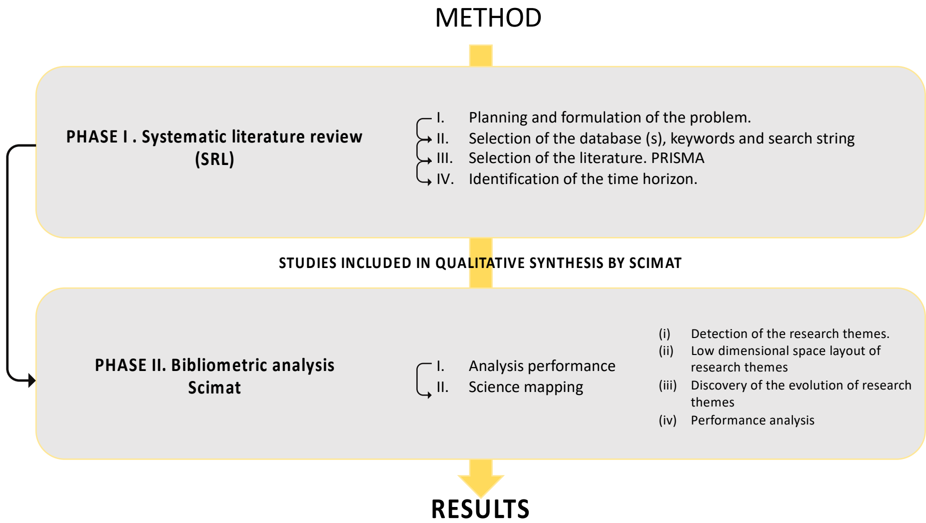

Figure 1. Materials and methods.

2.1. Systematic Literature Review

The SLR establishes a methodological approach that compiles all the empirical evidence that conforms to pre-specified eligibility criteria [30], in order to establish useful findings in the literature [31]. The SLR identifies any gap by minimising research bias and providing reliable results from which conclusions can be drawn and decisions made [32]. The review has been carried out following a search strategy and presents evidence on data sources, selection criteria and analysis [33] carried out according to the following four stages (Figure 1), according to Kitchenham's guidelines [34]:

- *Planning and formulation of the problem.* In this step, the SLR is planned, the problem is formulated and the scope of the review is set. To do that, it is necessary to have a clear definition of the proposed research questions, the exclusion criteria for the final selection of the significant documents and the definition of the expected results.
- *Selection of the database (s), keywords and the search string.* The second step defines the most appropriate bibliographic databases, search string and keywords for the document search. The main problem in carrying out searches in the databases is to determine the keywords and search chains that allow scientific documents relevant to the objectives of the research to be identified. In consequence, it should be necessary to have a large enough number of keywords to not restrict the number of studies, but it should be also specific enough to include only studies related to the research field under study. The first set of pre-selected records could be obtained thanks to the application of a search string.

- *Selection of the literature.* This is a key step to guarantee the selection of a significant number of relevant documents. The most relevant documents are those enclosing the data necessary to address the research questions of the SLR. They will be selected following the guidelines of the PRISMA flow diagram [35]. Flow diagram is a collective term for a diagram representing a flow or set of dynamic relationships in a system.
- *Identification of time horizon; selection of the database(s).* Finally, and before science mapping, it is essential to establish different periods based on the number of relevant documents identified, as well as the main elements and inflection points of the research field.

2.2. Bibliometric Analysis: Performance Analysis and Science Mapping

Bibliometric analysis was carried out by performance analysis and science mapping; its objective was the obtainment of a spatial illustration of the connection between disciplines, specialities, individual documents and authors [28]. The performance analysis quantifies the impact of the citation of scientific production; on the other hand, the mapping of science shows the social analysis, and the intellectual and conceptual evolution in field research, as well as its evolution and dynamic characteristics. To do that, the free scientific mapping tool SciMAT (Science Mapping Analysis Software Tool) [28] was used. This software is based on the analysis of co-words and the h-Index, incorporating methods, algorithms and measurements in the workflow of the general science mapping, from preprocessing to the visualisation of results [28].

The application of SciMAT enables the detection of the research themes, where an equivalence index [28] is generated, followed by the clustering of thematic keywords using the simple centres algorithm [36] in order to identify the most relevant themes. It continues with the creation of two-dimensional strategic diagrams based on the degree of interaction of different research topics (centrality) and the internal strength value of the research topic object of study (density). In these diagrams, the following four different research topics are reflected by periods (Figure 2a):

- Motor themes. These include important and developed topics in the research field.
- Highly developed and isolated themes. These are well developed topics, but, unlike motor themes, they are not important for the research field object of study.
- Emerging and declining themes. These include little-developed and non-important topics in the research field.
- Basic and transversal themes. These are important topics in the research field object of study, but they are not well developed.

Subsequently, conceptual links between research topics, in different periods, as well as the strength of association between the themes through the inclusion index [37] are detected. The following two types of graphics are used for their representation:

- Overlay graph (Figure 2b). The number of words shared by both periods is represented on the horizontal arrow. The upper incoming arrow shows the number of new words in period 2, and the upper outgoing one shows the words that disappear in period 2.
- Thematic evolution map (Figure 2c). The solid lines mean that the linked theme shares the main item; on the other hand, a dotted line means that the themes share elements that are not the main item. The volumes of the spheres are proportional to the numbers of published documents, and the thicknesses of the edges are proportional to the Inclusion Indices.

Additionally, the contribution of research topics to the whole field of research is quantitatively and qualitatively measured by bibliometric measurements. Among others, the number of documents published, number of citations of the documents, most cited authors, most cited publications and different variants of the h-index [38] are detected.

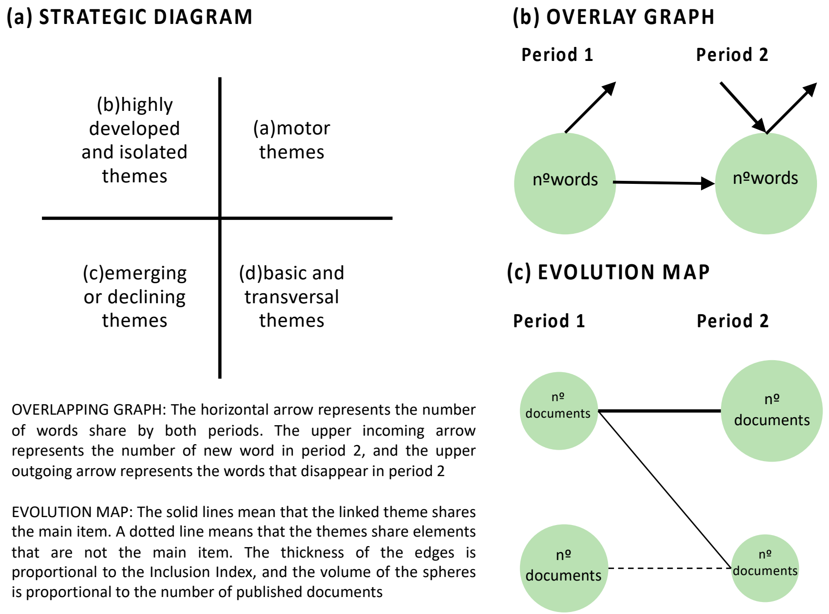

Figure 2. Example of (**a**) a strategic diagram, (**b**) overlay graph and (**c**) evolution map.

3. Results and Discussion

The SLR method and the science mapping study of the relevant documents were applied to carry out an exhaustive analysis of the OFMSW recycling treatment research field. The results obtained are summarised in Figures 3–6 and Tables 1–4, and they are described in detail in the following sections.

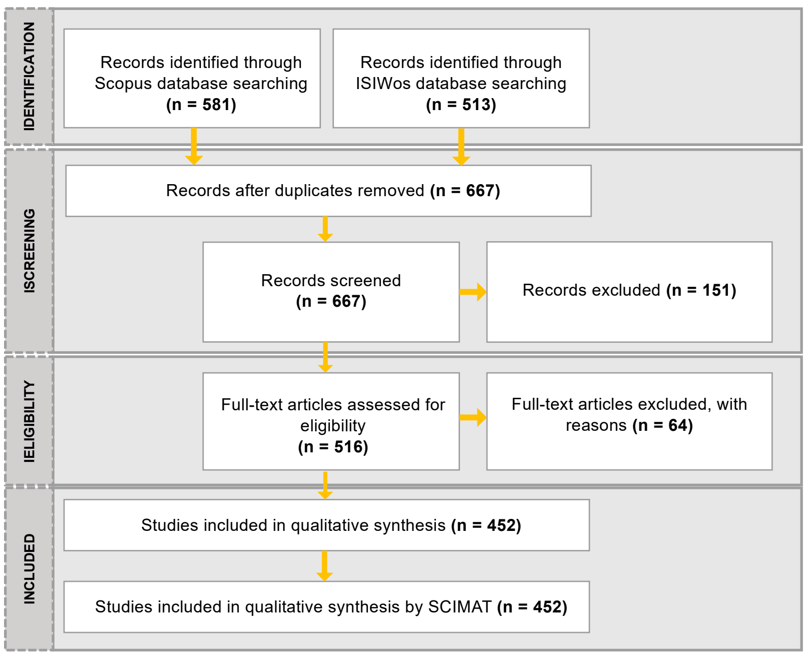

Figure 3. PRISMA flow diagram.

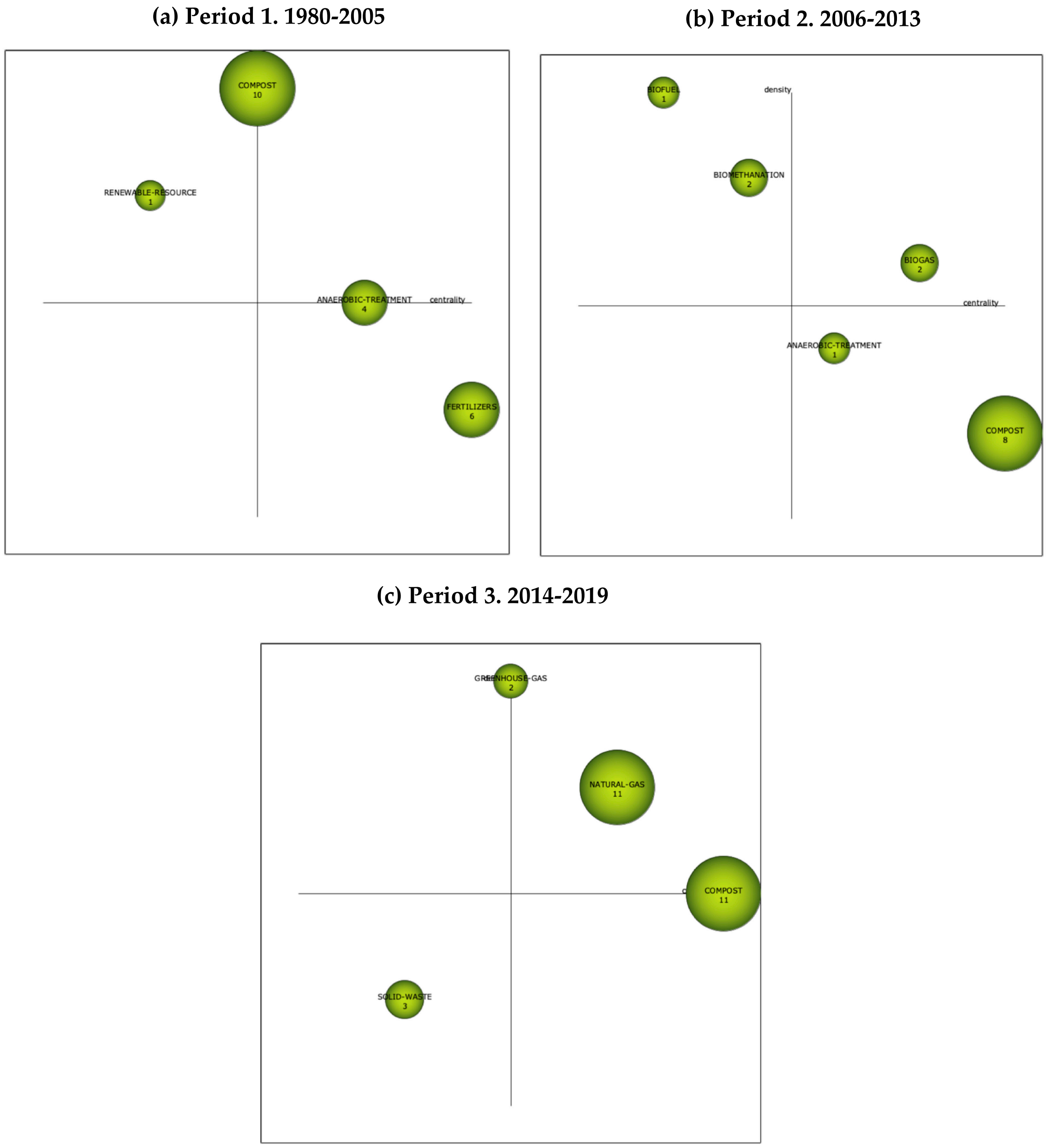

Figure 4. Strategic diagrams by period.

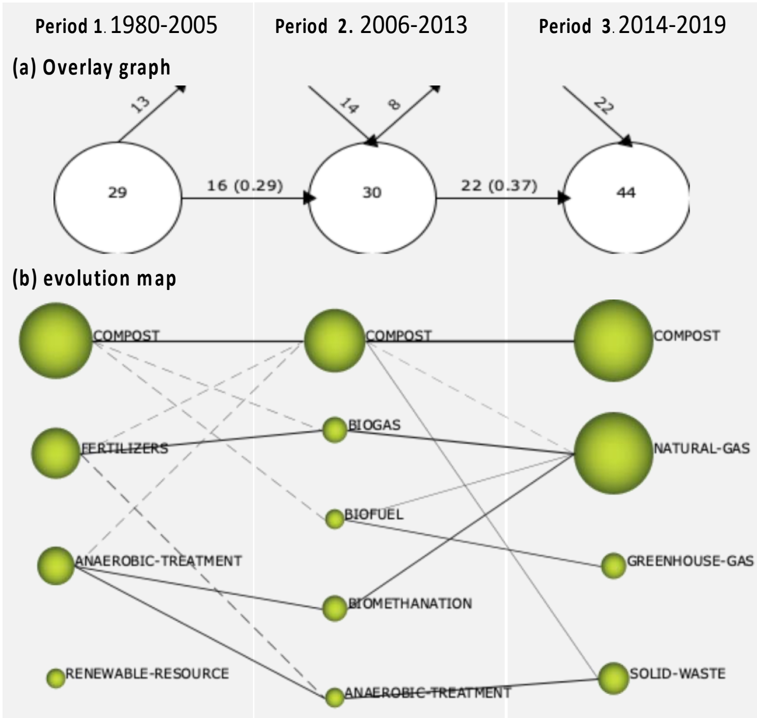

Figure 5. Overlay graph (**a**) and evolution map (**b**) of the research field by periods.

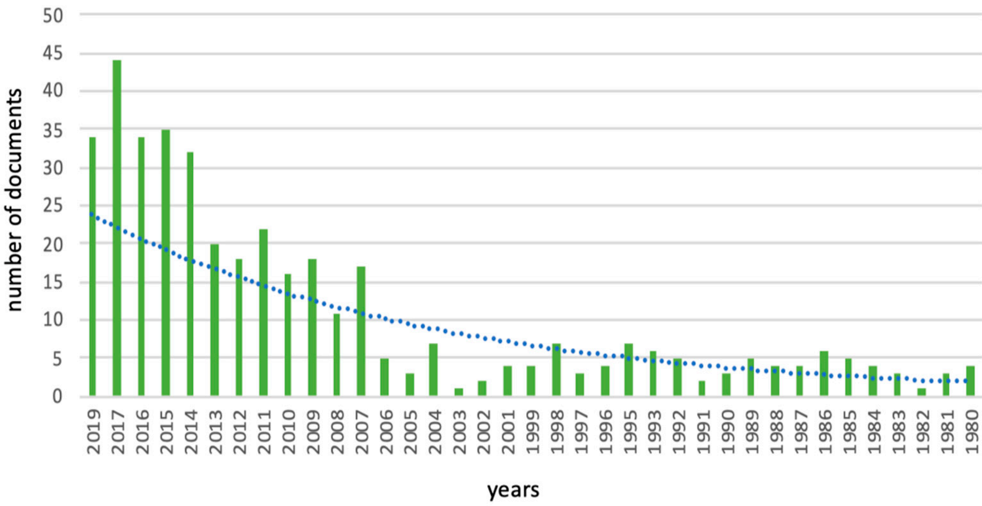

Figure 6. Documents per year.

Table 1. Documents by search strings.

Search String *	Records Scopus	Records ISIWoS
"Organic waste" AND "municipal solid waste" AND "biogas"	250	235
"Organic waste" AND "municipal solid waste" AND "biomethane"	19	21
"Organic waste" AND "municipal solid waste" AND "natural gas"	18	15
"Organic waste" AND "municipal solid waste" AND "network"	20	9
"Organic waste" AND "municipal solid waste" AND "compost"	274	233
Total Records	581	513

* Search completed 31 December 2019.

Table 2. Performance analysis by period.

Name	No. of Documents	No. of Citations	h-Index	Centrality	Density
Period 1 (1980–2005)					
Compost	10	116	5	7.94	32.98
Fertilizers	6	26	2	12.64	10.52
Anaerobic treatment	4	25	2	10.69	15
Renewable resource	1	0	0	3.21	25
Period 2 (2006–2013)					
Compost	8	36	2	8.75	9.63
Biogas	2	26	2	6.25	40
Biofuel	1	2	1	0	150
Bio methanation	2	1	1	0	50
Anaerobic treatment	1	2	1	0	12.5
Period 3 (2014–2019)					
Compost	11	31	4	19.47	14.05
Natural gas	11	32	3	15.54	39.31
Greenhouse gases	2	6	1	8.64	39.58
Solid waste	3	2	1	6.51	4.86

Table 3. Main publications contributing to the research field.

	Name	Total Number of Citations of the Journal on This Study	No. of Documents
1	Compost Science and Utilization	162	12
2	Agricultural Wastes	132	10
3	BioCycle	93	38
4	Environmental Engineering and Management Journal	66	10
5	Journal of Material Cycles and Waste Management	45	10
6	Polish Journal of Environmental Studies	21	6
7	Acta Horticulturae	17	11
8	Agronomy Research	16	7
9	Desalination and Water Treatment	11	5
10	Journal of Ecological Engineering	3	6

Table 4. Authors with more than ten published studies in the research field.

	Name	No. of Documents	Total Citations in This Work	h-Index
1	Dubrovskis, V.	4	3	3
2	Li, Y.	4	12	2
3	Kumar, A.	4	8	5
4	Cioabla, A.E.	3	2	4
5	Li, J.	3	12	9
6	Liu, H.	3	6	26
7	Kacprzak, M.	3	33	15
8	Zhao, Y.	3	7	15
9	Xi, B.	3	7	31
10	Guerrini, O.	3	5	4

3.1. Systematic Literature Review

The results obtained by applying the methodology of the SLR are presented below, including the definition of the research questions, the search process, the PRISMA flow diagram (Figure 3) and the data and search results collection.

3.1.1. Planning and Formulation of the Problem

The research questions were determined before starting the search. The SLR of this study addressed the following research questions (RQ):

- RQ1: What is the objective of this review?
- RQ2: What is the status of this study field?
- RQ3: Towards what topics is the field of research evolving?
- RQ4. What research topics are being addressed?
- RQ5. Who is leading the research?
- RQ6. What are the limitations of the current research?
- RQ7. Where are these papers published (e.g., journals, conferences)?

3.1.2. Selection of the Database, Keywords and Search Strings

Firstly, the Scopus and ISIWoS databases were selected because of their large numbers of international scientific publications and high impact techniques for any discipline. Secondly, the keywords related to OFMSW recycling were identified. Next, an advanced search was carried out in the field "Title/Abstract/Keyword" with the identified keywords and using the five search chains defined in Table 1. Finally, a total of 581 bibliographic records were identified for Scopus and 513 bibliographic records, for ISIWoS.

3.1.3. Selection of the Literature

Once these documents had been compiled, the guidelines of the PRISMA flow chart were applied to show the number of relevant documents (Figure 3). It can be seen that a total of 1094 bibliographic records were retrieved from the two selected databases. After removing 427 duplicates, 177 of the remaining 667 records were excluded based on their titles and abstracts; notes and errata were also excluded. The remaining 490 records were examined at the full-text level, which led to the exclusion of 86 additional records that did not cover the topics included in this study.

3.1.4. Identification of the Time Horizon

The recovery time interval of the literature was established from 1980 to 2019. To analyse trends in publication patterns, this time interval of the study was divided into three periods, considering both several relevant milestones and the number of documents selected. As a result, the following three periods were established:

- First period (1980–2005). Article 5 of Directive 31/99 (EUC, 1999) established that Member States had to develop a national strategy to reduce biodegradable waste disposal to landfill no later than two years after its publication. This strategy had to include measures to achieve the objectives established through recycling, composting, biogasification or the valorisation of materials/energy. Thus, not later than 2006, biodegradable municipal waste disposal in landfills had to be reduced to 75% of the total amount (by weight) of municipal biodegradable waste generated in 1995, and by 2016, to 35%. For this reason, the beginning of the first period established corresponds to the date of the first document selected; the end, the year 2005, corresponds to the first date established to reduce the organic matter deposited in landfill.
- Second period (2006–2013). The end of this second stage corresponds to the date of the second commitment period established in the Kyoto Protocol (2013), which ends in the year 2020. The Doha Amendment also applies, according to which the participating countries committed to reducing emissions by at least 18%, compared to 1990 levels. In the case of the EU, it undertook to reduce emissions by 20% below 1990 levels (United Nations, 1998).
- Third period (2014–2019). The end of this period corresponds to the date of the last articles included in the study, that is, the past year.

3.2. Bibliometric Analysis: Science Mapping and Analysis Performance

3.2.1. Science Mapping and Strategic Diagrams

From the analysis of the evolution of the strategic diagrams, the change in the development of the recycling of OFMSW can be seen, as well as the main milestones and inflection points. For the three periods considered (1980–2005, 2006–2013 and 2014–2019), and in order to analyse the temporal evolution, Figure 4 represents the strategic diagrams, showing the sizes of the spheres proportional to the numbers of documents published associated with each research topic. In addition, Table 2 shows the measures of performance obtained for each topic and period in terms of the number of documents, h-index, values of centrality and density. An analysis of these results, for each period, is discussed below.

- *First period (1980–2005).* According to the strategic diagram of Figure 4a, the following four main research topics can be found in the 97 papers published in this period: compost, fertilisers, anaerobic treatment and renewable resources. Two of them are considered motor themes (*compost* and *anaerobic treatment*); one, transversal (*renewable resource*); and, finally, another, a basic one (*fertilizers*). The performance analysis for each topic (Table 2) complements the information provided by the strategic diagram; it may be observed that *compost* and *fertilizer* are the themes with a significant impact rate; they receive more than 100 citations and obtain higher h-indices compared to the remaining themes. These research topics show that the first treatments of the organic fraction of urban waste were aimed at producing compost to be used as fertiliser, applying simple technologies for the aerobic stabilisation of the biodegradable fraction.
- *Second period (2006–2013).* According to the strategic diagram of Figure 4b, in the 127 papers published in this period, an increase in research topics is seen, rising to five: *compost*, *biogas*, *biofuel*, *biomethanization* and *anaerobic treatment*. One of them is considered a motor theme (*biogas*); two, transversal (*biofuel* and *biomethanization*); and, finally, two of them are basic themes (*anaerobic treatment* and *compost*). The performance measures included in Table 2 reveal that *compost* and *biogas* are the most noted research topics. They obtained an important impact rate and achieved higher h-indices in comparison with the remaining topics. It can be seen that the application of the waste management hierarchy and the obligation to achieve the established objectives to reduce the percentage of biodegradable waste disposal in landfill have led to an evolution of the treatments towards anaerobic stabilisation or biomethanisation technologies in order to obtain a biogas that can be used to produce energy, as well as a digestate that, after a composting phase, can be used in agriculture.
- *Third period (2014–2019).* Finally, in the last period (Figure 4c), there is a greater number of documents (245), so it is possible to differentiate four research topics: *compost*, *natural gas*, *greenhouse gases* and *solid waste*. Three of these research topics are considered motor themes (*compost*, *natural gas* and *greenhouse gases*), and only one of them is classified as declined (*solid waste*). The performance measures highlight two research topics: compost and natural gas; they show an important impact rate and achieve higher h-indices compared to the remaining topics. Although the compost theme appears as the main one, research focused on the use of biomethane in natural gas networks emerges as a way to reduce Greenhouse Gas (GHG). This is a clear example of the important role of waste management in the decarbonisation of the energy system.

3.2.2. Science Mapping, Overlay Graph and Thematic Evolution Map

The systematic analysis of the literature has shown the change in the development of the treatments for recycling OFMSW, as well as the main milestones and inflection points. Next, it was considered interesting to carry out a joint analysis of the evolution of the keywords and the thematic evolution of the field of the investigation. The results are shown in Figure 5 and discussed below.

The number of keywords per period and their evolution have been represented in Figure 5a, as well as the number of incoming and outgoing keywords, and the number and percentage of keywords that remain from one period to the next. It can be seen that the number of keywords increases over the periods, in parallel with the rise in the number of documents over the years. Thus, the number of keywords increased from 29 to 44 between the first and last periods, which meant a growth of 51.7%; this result indicates that the field of research is diversifying and continuing to increase, meaning that it is not yet a consolidated field. The increasing number of words and keywords shared between successive periods proves the growing thematic diversity of the field of research on the recycling of OFMSW.

Figure 5b shows the thematic evolution of the field of research thanks to the analysis of its origins and its interrelations. The thickness of the lines represents the strength of the association measured by the inclusion index. The analysis of the graph from the point of view of the number of documents shows that the four thematic groups of the first period (1980–2005) have progressed towards different concepts; thus, the compost theme appeared with the largest number of central documents in 1980–2005, evolving into the topics of biogas, biofuel and new compost in 2006–2013; in the last period (2014–2019), compost appears again with the largest number and has evolved into the topics of natural gas and solid waste. On the other hand, the fertilisers thematic group has evolved towards anaerobic treatment, compost and biogas in the period of 2006–2013, to finally evolve to natural gas in the last period; this result reveals again the evolution of the by-products of the treatments used in the stabilisation of organic matter.

Finally, it is noteworthy that the compost thematic group of the first period was kept with the same label in the second and third periods but with a greater number of central documents published during the last one (2006–2019). In the same way, the anaerobic treatment thematic group of the first period was maintained with the same label in the following period, although with a lower number of documents, evolving towards the solid waste thematic group during the last period.

3.2.3. Performance Analysis

After the SLR was performed, a total of 452 documents published within the time horizon (1980–2019) were obtained. Finally, the following configuration in SciMAT for the bibliometric analysis was established: (i) the word as the unit of analysis, (ii) the analysis of co-occurrence to build the networks, (iii) the index of equivalence to measure the similarity to standardize the networks, and (iv) the k-means clustering algorithm to detect the themes; finally, documents were analysed taking into account the year of publication, journals cited, authors and number of citations. The results obtained are summarised below:

- Documents per year. Figure 6 shows the distribution by year of the 452 publications selected. It is worth stressing that, in general terms, the number of studies was not high, except in the year 2017, when it exceeded 40. Before 2007, no more than eight publications related to the research field analysed were observed per year; however, since 2007, a continuing increase in the number of articles can be seen. This result highlights the obligation to apply Article 4 of Directive 2006/12/EC of the European Parliament and of the Council of 5 April 2006 on waste, which established the obligation to apply the waste management hierarchy; it indicates an order of preference for management hierarchy that reduce the production of waste and capture the progression of a material or product through consecutive phases of waste management, and it includes, in this order: prevention; preparation for reuse; recycling; another type of valorisation, for example, energy recovery; and elimination.
- Most relevant journals. A total of 192 journals were identified in this analysis. Table 3 shows the journals of 28.5% of the documents analysed, classified in descending order according to the number of citations of the document. Most of these research journals focus on the application of processed organic solid waste, biogas utilisation, energy policy and soil science, among others. Table 3 also includes the most cited publications in each journal; it should be noted that the numbers of publications and citations are closely related, except for the BioCycle journal; that is, the most prolific sources are those with the greatest impact in the research field.
- Documents by author. A systematic literature review and performance analysis allowed the identification of a total of 1329 authors who have published on the theme addressed by the study's objective. Table 4 shows those authors with more than three published studies, as well as the total number of documents published and citations received; the h-index (Hirsch index), has been also included as a measure of the authors' professional quality, taking into account the number of times that their scientific articles have been cited [39]. According to the information analysis, Dubrovskis, V., Li, Y. and Kumar, A. have published the most articles on them, although Xi, B. has the highest h-index.

4. Conclusions

This document shows an analysis of the scientific literature that addresses the treatment of the biodegradable fraction of urban waste from 1980 to 2019. To do this, a transparent, rigorous and reproducible research procedure was applied to a collection of 452 articles published in indexed journals in the ISI Web of Science (ISIWoS) and Scopus database, with peer review before publication. Tendencies were analysed, considering an overview and a more specific analysis of three different time intervals during the period under review (1980–2005, 2006–2013 and 2014–2019).

The study has shown that the application of technologies that allow the use of the OFMSW as a biological nutrient in the framework of the circular economy is relevant, especially in recent years. In fact, the results show a regular rise in the number of studies published since 1980; this rise is more significant since 2014, when policies aimed at reducing emissions to the atmosphere through the development of renewable energies were increased. Although the treatments of this fraction have been applied for years, the scientific field is still evolving; this may be explained by the evolution of the legal framework, which imposes the need to continue working on the implementation of strategies to develop a model of a circular economy. One of the basic pillars of this new framework is the use of bioproducts, such as OFMSW, as a renewable energy resource.

The systematic analysis of the literature has shown the evolution of recycling treatment for OFMSW, as well as the main landmarks and inflection points. On the other hand, the strategic diagrams show the interest of researchers in different key issues, which have progressed from simple treatments, just applied to produce compost from the biodegradable fraction of municipal waste, up to its use to produce biofuel; this last application is within the framework of policies aimed at promoting the use of renewable energies that reduce the emissions of greenhouse gases.

This document has shown that emerging studies in this area are being conducted on the production of biomethane, called green gas, for application as fuel in vehicles or for injection into natural gas networks. Although these applications are currently in use, they are still not competitive, but their contribution to their circular economy as a sustainable alternative to waste disposal, as well as to reduce greenhouse gas emissions, is already clear. Biomethane is thus positioned as a fundamental element in the energy transition that will contribute to a decarbonised energy system in order to comply with global objectives.

The above findings provide researchers and professionals in the OFMSW recycling field with a detailed understanding of the status quo, predicting its dynamic directions; in consequence, this study is a valuable contribution to research concerning this field.

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