

Industrial waste in the food science and technology area: a bibliometric study from 1990 to 2019

Dayane Santos Conceição Soares

Graduate Program in Intellectual Property Science, Federal University Sergipe,
São Cristóvão, SE 49100-000, Brazil.

Daniela Almeida dos Anjos

Department of Food Technology, Federal University Sergipe,
São Cristóvão, SE 49100-000, Brazil.

Márcio Nannini da Silva Florêncio

Graduate Program in Intellectual Property Science, Federal University Sergipe,
São Cristóvão, SE 49100-000, Brazil.

Ana Karla de Souza Abud

Graduate Program in Intellectual Property Science, Federal University Sergipe,
São Cristóvão, SE 49100-000, Brazil.

Antônio Martins de Oliveira Júnior (Corresponding author)

Graduate Program in Intellectual Property Science, Federal University Sergipe,
São Cristóvão, SE 49100-000, Brazil.

*Corresponding author. E-mail: amartins.junior@gmail.com

Abstract

In recent years, due to the potential of its properties, the use of industrial waste has generated interest of study in the academic community in the area of Food Science and Technology (FST). The goal of this work was investigate the importance of food industrial waste by bibliometric tools in articles, reviews and proceeding papers published in the last 28 years. It was verified that the research on industrial residues in the area of FST has evolved over the years, being more remarkable from the year of 2006. The research found 1453 documents published in 183 journals. The 7 most productive countries were analyzed, with Brazil being highlighted due to greater predominance of publications in the area. It was observed that antioxidant activity, extraction, optimization, by-products and purification have attracted great attention to food and/or cosmetic industries.

Keywords: waste; industry; food; bibliometrics; reuse.

1. Introduction

With industrial growth, great amounts of waste and an excessive ecological footprint have caused great

damage to the environment and to the quality of life of great part of the world's population. Some of this waste remains in their production or extraction sites, with no associated economic or social advantages to local producers, with most of this waste being located in developing countries [1].

This is usually low value-added industrial waste, being commonly heterogeneous. Furthermore, it can cause great harm, namely in terms of water pollution, endemic diseases, also contributing to a lower quality of the air, besides leading to social and economic problems. These consequences become even greater when large industries discard residues in highly vulnerable regions, with not enough resources available for their treatment [2].

In order to prevent such issues, industries should carry out an adequate treatment of these residues. Nevertheless, most treatments do not completely remove all waste generated. Thus, an alternative lies on reusing these residues, which has been employed for reducing their disposal to the environment. Taking into account that most residues can contain substances with high added value, the application of appropriate technologies result in new products or in feedstock to be used in other processes [3].

This concept is the backbone of sustainable industries, aimed at reaching a zero-waste society, with an economy which uses waste as feedstock for the production of new products and applications. Closed systems are the base for industrial symbiosis, using residue from a certain sector to be applicable in others [4].

In the food processing and agroindustry, the generation of waste and by-products is considered a great issue, having raised the attention of researchers, regulatory bodies, industries and consumers. New scientific researches have shown ways and opportunities of reusing this waste or by-products by developing innovative value-added products with high economic importance [5].

The complex organic content present in these residues are a great source for the development of biotechnological processes, through the introduction of new treatment methods and policies. The conversion of waste generated from food processing has been of great attention, as this waste content represents a valuable resource for forming new useful products, mainly due to its low cost, accessibility and high nutrient content [6,7].

Agroindustrial and food waste has been potentially applied within the Food Science and Technology (FST) area, mainly for the development of new products. The use of processing technologies enables the extraction, fractionation and recovery of ingredients of high added value, with important biological activities, such as antioxidant, anti-cancer and anti-hypertensive activities [8]. Sepúlveda et al. (2018) [9] highlight the sustainable character of the use of food by-products, which can be used not only for obtaining value-added products (such as chemical products and materials, as well as fuels), but also in the reduction of environmental impacts and in the improvement of economic growth.

Some agroindustrial residues or by-products have already been used in the production of new compounds. For instance, waste originated from apple and citric fruit processing has been applied in the production of dietary fibre. Nevertheless, the composition and physicochemical properties of these fibres depend on the characteristics of the material and on the processes employed [10]. Other examples include the production of lactic acid, biosurfactants and bioethanol, as well as the fermentation of shells of citrus fruits [11]. Moreover, tomato processing waste, such as tomato skin and seeds, can be used in the extraction of carotenoids [12]. The production of olive oil also generates a great amount of residues, which are rich in

phenolic compounds, being of great biological and pharmaceutical interest [13].

With this in mind, the present work is aimed at analyzing the scientific production of industrial waste in the Food Science and Technology area, based on a bibliometric study. With this study, it was possible to identify how this type of waste has been used in this academic field, as well as which countries and entities have published the greatest number of researches, also assessing their respective impact through a citation analysis.

2. Materials and Methods

The bibliometric research was carried out with the data collected from the Web of Science (WoS) database, published by Thomson Reuters, as it is considered a reference for this type of analysis [14]. This study was performed using the following keywords: “industrial and waste” or “industrial and residue”, with a filter being selected for the Food Science and Technology (FST) area. The study period ranged between 1990 and 2019, covering the most important years of scientific research publications. This study was carried out in August 2019, with 1,466 documents being collected.

The data were analysed and presented using Microsoft Excel ® version 2010 and VOSviewer® for drawing the maps, graphs and tables that demonstrate the different results of scientific production. In addition, HistCite was employed in the data collection from Total Global Citation Scores (TGCS) and Total Local Citation Scores (TLCS). The impact factor for the scientific journals in the last five years was collected from Journal Citation Reports (JCR) 2019.

3. Results and Discussion

Among the publications found in the WoS, 10 documents were found. Most publications were classified as articles, with approximately 83.97%, followed by reviews (11.11%) and proceeding papers (7.09%). The remaining types included meeting abstracts, new items, retracted publications, notes, editorial materials, correction additions and book chapters, which represented a total of only 0.88% of all publications. For greater relevance of the search performed, only articles, reviews and proceeding papers were considered for the analysis of this work, with a total of 1,453 documents.

Figure 1 shows a gradual increase in publications on industrial waste in the area of Food and Science Technology (FST). Between the period from 1990 to 2006, only a few publications on this subject could be found, with an almost stable period, being mostly dominated by developed countries, such as Japan, the United States and Germany (Figure 2). From 2006, there was a rapid increase in the number of publications, growing from 19 to 169 documents in 2018. This upsurge was favored by the start of publications from countries such as Brazil and China, which, until then, had no document published, as well as Spain, which also intensified their studies from 2006. This trend demonstrates that researches regarding industrial waste in the FST area started to become more important to researchers due to the relevance of the topic and the alternative of reusing this type of waste, with a positive effect on the number of works published over the last years.

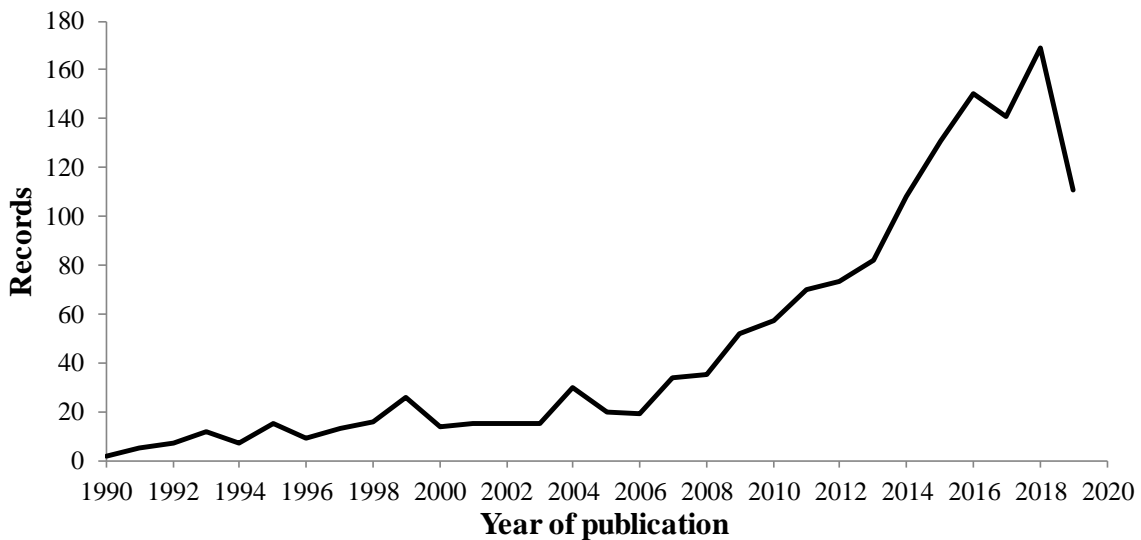


Figure 1. Chronological distribution of publications on industrial waste in FST.

Figure 2 shows the seven countries with most publications on industrial waste in the FST area. Among these, it can be observed that 4 countries are classified as developed countries (Spain, Japan, USA and Italy) and 3 being developing countries (Brazil, China and India). Brazil was the country which published the greatest number of studies in the area being analysed, with a total of 194 documents, followed by Spain and China, with 157 and 121 documents, respectively. Thus, Brazil is considered to have a greater research influence in this subject, in terms of the number of publications. It is worth noting that, from 1990 to 2005, the USA and Japan were among the most influential countries in terms of studies published. However, after this period, countries such as Brazil, Spain and China observed a significant increase in the number of publications.

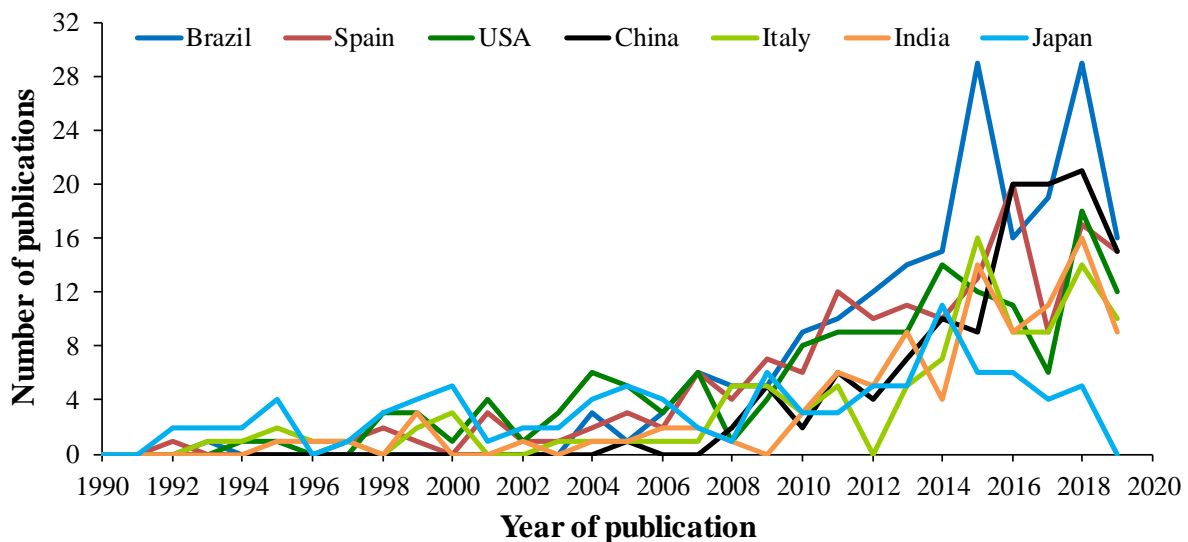


Figure 2. Ascending trends of publications from the seven main countries from 1990 to 2019.

Approximately 200 institutions have publications on this subject, with the 12 most productive institutions being presented in Table 1, as well as their respective citation indices. A citation index is an important

analysis tool, as it an indication of the quality of the articles produced, according to the citations in the scientific community (Chen et al., 2017) [15].

Table 1. Most productive institutions in the period between 1990 and 2019.

Institution	RECS	TLCS	TGCS	TLCS/ RECS	TLCS/ TGCS (%)
State University of Campinas, Brazil	32	15	827	0.469	0.018
Superior Council of Scientific Investigations, Spain	28	6	565	0.214	0.011
University of Vigo, Spain	27	31	1606	1.148	0.019
University of Sao Paulo, Brazil	24	2	524	0.083	0.004
National Institute for Agricultural Research, France	14	3	454	0.214	0.007
State University of Maringa, Brazil	13	3	59	0.231	0.051
University of Minho, Portugal	13	16	518	1.231	0.031
National Council of Scientific and Technical Research, Argentina	12	6	125	0.500	0.048
Aristotle University of Thessaloniki, Greece	11	20	391	1.818	0.051
Federal University of Rio de Janeiro, Brazil	11	7	92	0.636	0.076
Federal University of Rio Grande do Sul, Brazil	11	7	300	0.636	0.023
Jiangnan University, China	11	3	158	0.273	0.019

RECS: Records; TLCS: Total Local Citation Score, represents the number of times a given article is cited by other articles within a local collection; TGCS: Total Global Citation Score, represents the frequency of citations based on the WoS count at the time the data were collected.

The institutions with the greatest number of publications regarding industrial waste in the FST area are from Brazil, Spain, France, Portugal, Argentina, Greece and China. In Brazil, the State University of Campinas (UNICAMP) produced most documents in terms of the number of publications (2.2%), followed by Spain, with the Superior Council of Scientific Investigations (1.9%). Regarding the citation indices Total Global Citation Scores (TGCS) and Total Local Citation Scores (TLCS), the University of Vigo appeared in the first position, with the highest scores. Aristotle University of Thessaloniki, the University of Vigo and the University of Minho exhibited the highest (TLCS/TGCS) indices, thus demonstrating that these institutions produced articles with greater visibility in the subject when compared to the remaining institutions. On the other hand, Brazilian Universities, such as the Federal University of Rio de Janeiro and the State University of Maringá, presented the highest number of citations in this subject, when considering the total citations in the WoS.

Nevertheless, it could be observed that the most productive institutions had lower (TLCS/TGCS) indices, indicating that they are more cited in other fields of knowledge.

The main journals and their corresponding citation indices and factors of impact are shown in Table 2. The greatest number of publications was observed in the Innovative Food Science & Emerging Technologies Journal, followed by Food Chemistry and the Journal of Agricultural and Food Chemistry, which represented

19.89% of all publications in the 183 journals analyzed. When considering the TLCS indicator, Food Chemistry and Innovative Food Science & Emerging Technologies exhibited the highest values. In turn, Food Chemistry and the Journal of Agricultural and Food Chemistry obtained the highest values of TGCS. The journals with the greatest impact factor are Innovative Food Science & Emerging Technologies and Food Chemistry, being considered the most influential journals, as both also have a high number of publications, as well as high TLCS and TGCS.

Table 2. Most productive journals from 1990 to 2019.

Journal	RECS	TLCS	TGCS	FI
Innovative Food Science & Emerging Technologies	109	45	2325	4.41
Food Chemistry	99	93	4664	5.488
Journal of Agricultural and Food Chemistry	81	29	2397	3.911
Journal of the Science of Food and Agriculture	46	12	608	2.733
Food Research International	42	28	1026	4.437
Journal of Bioscience and Bioengineering	41	11	969	2.244
Food and Bioproducts Processing	38	24	837	3.518
European Journal of Lipid Science and Technology	34	6	393	2.207
Biotechnology Progress	31	4	2192	2.488
International Journal of Food Science and Technology	31	15	278	2.201
LWT-Food Science and Technology	31	14	478	4.0
Journal of Food Engineering	30	20	627	4.051
Journal of Food Science and Technology-Mysore	26	8	150	2.391
Analytical Methods	25	0	212	2.145
Food and Bioprocess Technology	25	29	1178	3.449
Journal of Food Process Engineering	25	1	111	1.441

RECS: Records; TLCS: Total Local Citation Score, represents the number of times a given article is cited by other articles within a local collection; TGCS: Total Global Citation Score, represents the frequency of citations based on the WoS count at the time the data were collected; FI: Factor of Impact.

The chronological distribution of the publications in the five journals that received most publications are presented in Figure 3. Between 1990 and 2006, it was observed that only 5 journals published researches, including Food Chemistry and the Journal of Agricultural and Food Chemistry, with a maximum number of 2 publications a year. From 2006, there was a promising increase in the number of publications in the area of FST, especially in the first three journals presented in Table 2. Subsequently, in the year of 2006, the journal Food Science & Emerging Technologies gained distinction in this scenario for the number of documents published. These journals have similar interests, comprising the areas of food chemistry, food science and agriculture. Most publications are related to the use of industrial waste originated from agriculture or food industries for the production or synthesis of new chemical substances for food purposes, energy production and for products for human or animal consumption.

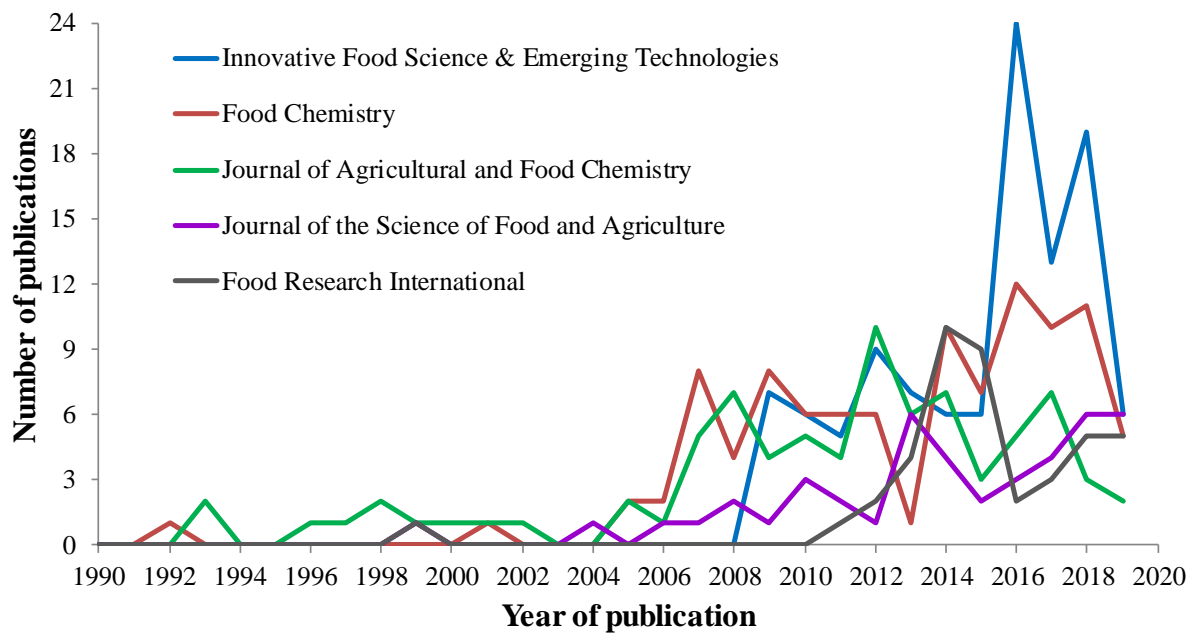


Figure 3. Ascending trends of publications from the main journals between 1990 and 2019.

The documents were mostly published in English (95.93%), followed by German (1.72%), Japanese (1.03%), among other languages (1.16%), especially Portuguese, Italian, Polish, French and Spanish. The preference for the English language can be associated to the greater visibility of publications within the academic community [16]. Although Brazil is among one of the countries with the highest number of publications in the field studied, Portuguese was not the language used by the respective authors, as English is the language with the greatest acceptability in the academia.

The impact analysis of the articles was based on the number of times each article is cited (Figure 4). Up until when the data was collected, approximately 16% of the articles published had not been cited, with 26.8% having between 1 and 4 citations. Approximately 83.82% of the 1,453 documents on industrial waste in the FST area had been cited. The total number of citations was of 27,582, with an average of 18.98 citations per article, with the article with the most citations having 1,549 citations. In addition, the mode obtained was equal to 0, with a median of 6.

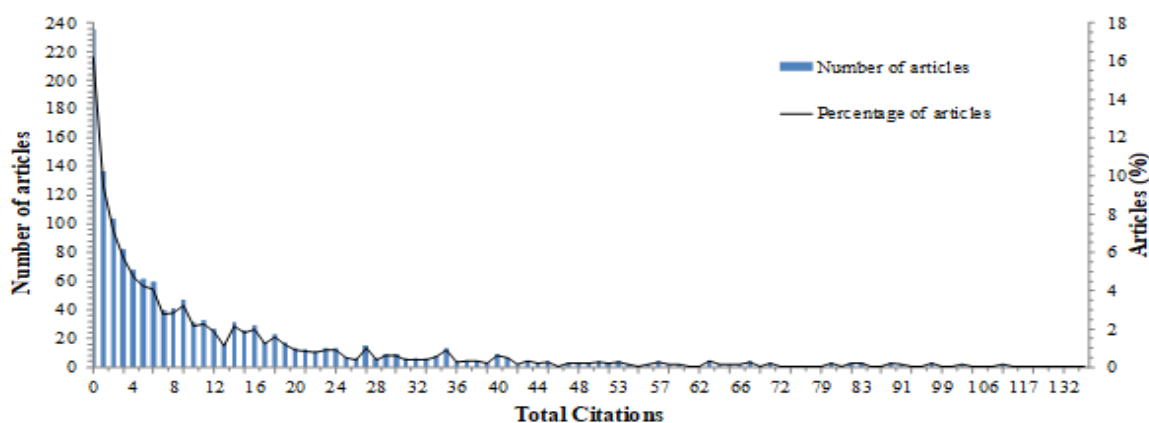


Figure 4. Distribution of the number of citations per article between 1990 and 2019.

The analysis of the keywords used by the authors was carried out aimed at verifying the trends of research on industrial waste in the FST area. Accordingly, 7,975 keywords were used in the period between 1990 and 2019. Moreover, 86.51% of the keywords were used only once or twice, while the keywords used 3 or more times represented 13.49%, totalling 1,076 words. This shows that the researches are not concentrated in only certain areas of knowledge, being, instead, quite diversified.

Figure 5 illustrates the most frequent keywords in the field of knowledge studied. The lines between the words and their proximity represent the overlaps between these words, with the academic subject clusters being represented in different colours. As observed in Figure 5a, there are three clusters, with the largest consisting of 10 keywords and the smallest with 8 keywords. The words with the highest incidence include: antioxidant activity (114), extraction (108), optimization (108), by-products (93) and purification (93). The words that have a greater association with other words include antioxidant activity, extraction and optimization. According to Figure 5b, these keywords were mostly used after 2013, especially those regarding bioactive compounds and antioxidant capacity. The discovery of antioxidants with benefits to human health is of great importance to scientists worldwide, having been of increasing interest in the last two decades [17].

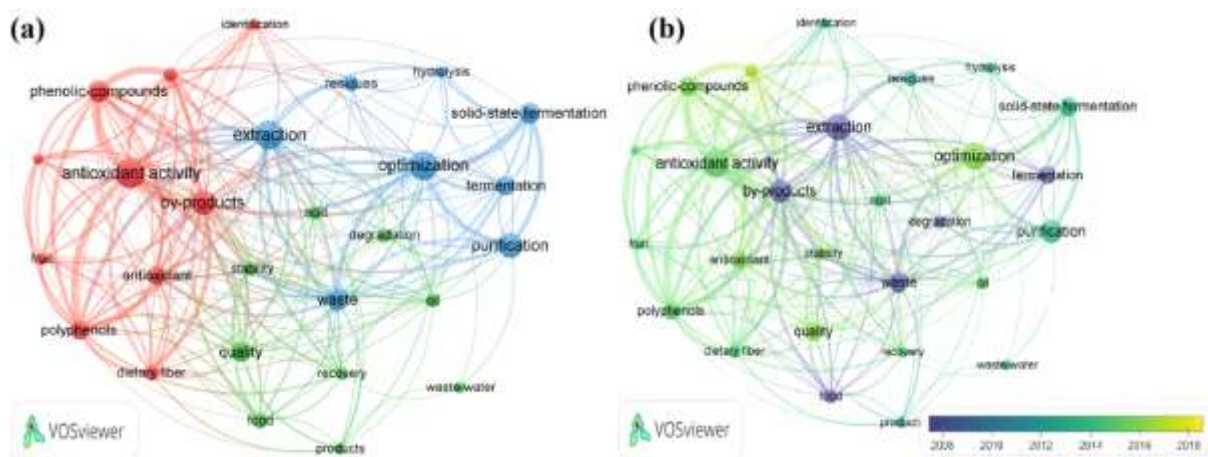


Figure 5. Incidence of the main keywords (a) Academic subject clusters and the relationship between keywords; (b) Incidence of keywords between 2000 and 2019.

The trends of researches on bioactive compounds and their antioxidant capacity lies on the fact that these compounds are extremely relevant for the scientific community due to their medicinal properties and benefits to human health [18]. Moreover, there is great interest in exploring the antioxidant capacity of several phenolic compounds originating from natural sources, aimed at replacing synthetic antioxidants from food products [19]. Several types of waste from food processing or the agroindustry exhibit great quantities of these compounds, thus, being of great interest to scientific research, such as in the case of seafood waste and wine production waste. The use of these types of waste enables the development of food or comestic products, besides reducing environmental pollution [20, 21].

This demonstrates the relationship between the most cited keywords (antioxidant, polyphenols and by-products) and agroindustrial waste. Consequently, it also shows the main fields of interest in terms of the application of agroindustrial waste in the FST area, allowing greater knowledge regarding the alternatives

for reusing these residues.

4. Conclusion

The present bibliometric study performed with 1,453 documents from the Web of Science database provided a systemic view on the current trends of research on industrial waste in the area of Food Science and Technology, with some important aspects being pointed out.

The subject studied is considered recent, having observed a rapid increase of interest after 2006. From 1990 to 2006, developed countries (USA, Japan and Germany) were more predominant in terms of the number of publications. After 2006, countries such as Brazil, Spain and China became more prominent, with Brazil having the greatest number of publications in the field. In addition, it was verified that, despite the Brazilian State University of Campinas having the greatest number of publications, the Spanish University of Vigo obtained higher citation indexes of Total Global Citation Scores (TGCS) and Total Local Citation Scores (TLCS). The most influent journals were Innovative Food Science & Emerging Technologies and Food Chemistry, with both having the highest number of publications and factor of impact, as well as high citation indicators.

As anticipated, the most commonly used language for publication was English, accounting for 95.93% of the articles cited. The most frequent keywords used by authors were antioxidant activity, extraction, optimization, by-products and purification, indicating a trend of researches on industrial waste, which focuses on the development of products with applications in the food and/or cosmetic industries.

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Highlights

- increasing number of publications involving the use of industrial waste.
- bibliometrics tools to prospect main areas of research on industrial waste.
- recovery is directly related to cleaner production, waste minimization and recycling.
- Institutions from Brazil and Spain stand out in the publication on industrial waste.