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A Bibliometric Analysis of Biodegradable Products in Circular Economy and Consumer Perception

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Abstract.

The transition towards a global circular economy is widely acknowledged as one of the most promising solutions to counteract resource depletion and environmental deterioration. In alignment with this perspective, there has been a rise in the availability of environmentally friendly products in the consumer market. This shift towards sustainable production and consumption patterns has led to a surge in scholarly interest surrounding biodegradable studies, particularly from the consumer viewpoint, within the context of the circular economy. However, the exploration of this topic, especially concerning the consumer perspective and its role in the circular economy, remains limited in the existing literature search. With the ongoing progression towards a circular economy, there is an evident need for a deeper understanding, extracted from available literature. Utilizing a bibliometric analysis approach, this study aims to enhance comprehension of the present knowledge landscape and delineate potential future research directions linked to consumers' roles in the transition from a linear to a circular economy, as well as their intent to adopt biodegradable products. Employing boolean operators and wildcard searches, a topic exploration was conducted within the Web of Science (WoS) core collection database on August 22, 2022. The study spanned from the first publication in the field in 2017 to the current date. A total of 51 documents were retrieved for comprehensive bibliometric analysis. To visualize research productivity and bibliometric insights, Tableau and VOSviewer were employed as presentation tools. The findings unveil the involvement of 223 authors hailing from 26 countries. The top three research areas encompass Environmental Sciences Ecology (35.3%), Science Technology Other Topics (33.3%), and Engineering (29.4%). Notably, the majority of significant contributors originated from the United States. Leading the pack of core publication journals is the Journal of Cleaner Production, cited 129 times in WoS. Co-authorship and country collaboration networks indicate a minimal level of partnerships. Through keywork co-occurrence network analysis, three prominent themes were identified: process, materials, and consumers. This analysis distinctly elucidates various developmental stages as well as nascent dimensions that constitute potential focal points for future research agendas in the field.

Keywords: bibliometric, biodegradable, circular economy, consumer, WoS

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1. Introduction

Transitioning into a global circular economy (CE) is well recognised as one of the most promising solutions to mitigate resource depletion and environmental degradation. As Olga Algayerova, UNECE Executive Secretary, made a remarkable note, "The circular economy is a compulsory choice for a sustainable world". Over the decades, a global nonprofit charity, Ellen MacArthur Foundation (2013) has been promoting the transition to circular economy which aims to increase the efficient use of resources and minimize the waste produced without damaging the environment. Based on the three principles, the early stage of CE implementation focused on the production sector to design the products with the highest utility and value by regenerative and eliminating waste. One of the sustainable innovations in the circular economy is vitalizing the anaerobic digestion or composting process on biological material to reduce greenhouse gas emissions (Ellen MacArthur Foundation, 2013).

In line with it, there have been emerging environmentally friendly products in the consumer market. Owing to the shift in sustainable production and consumption pattern, scholarly interest in biodegradable relevant studies has gained prominence in recent decades. Most recent biodegradable studies in circular economy focused on biodegradable films from vegetative and food waste (Gupta, Toksha, & Rahaman, 2022), biodegradable plastic industry (Moshood, Nawanir, Mahmud, Mohamad, Ahmad, Abdul-Ghani, & Kumar, 2022), agricultural/plant-based materials (Shogren, Wood, Orts, & Glenn, 2019), and process of biodegradation (Wang, Lydon, White, Grubbs, Lipp, Locklin, & Jambeck, 2018). Most of the studies emphasised the importance of developing biodegradable products and they could impact the environment, social and economic. However, limited review studies on the topic particularly from the consumer perspective in the context of circular economy are found in the search. More knowledge is critically needed and should be obtained from existing literature as the transition to the circular economy is still in progress.

By using a bibliometric analysis approach, this study attempts to improve the understanding of the current state of knowledge and outline future research scope that associated with consumers' role in transitioning from a linear to a circular economy and intention to switch to biodegradable products. One of the advantages of using bibliometric analysis is to provide a structured overview of existing publications on the research topic. As bibliometric analysis is based on quantitative data, it could increase the accuracy by reducing the reviewers' subjectivity and bias, especially in management research (Marzi, Dabic, Daim, & Garces, 2017). Additionally, a well-established protocol

of bibliometric studies could offer a novelty in the research field of study with a strong foundation for future research (Donthu, Kumar, Mukherjee, Pandey & Lim, 2021).

Therefore, this study aims to offer (1) an overview of the biodegradable products in circular economy and consumer perception, (2) identify newly emerging dimensions for future agenda in the field of the study, and (3) step-by-step guidelines for conducting bibliometric analysis for business research.

2. Data and Method

To explore the emerging body of knowledge on the topic of biodegradable products in circular economy and consumer perception, this study is developed based on two main steps: (i) search strategy and data collection, and (ii) bibliometric analysis. The entire process is described in detail in the following sub-topics:

2.1. Search strategy and data collection

2.1.1. Defining search keywords

Setting an appropriate search strategy is a critical step to collect relevant and accurate sample data for bibliometric analysis. As a first step, a set of keywords related to the scope of the topic was identified with guidance from existing literature. In this study, three domain search keywords were identified: circular economy, biodegradable products and consumers. For example, the first keyword is circular economy, search keywords are defined as "circular econom*" and "circularity" (dos Santos Gonçalves & Campos, 2022; Sucheck, et al., 2021).

2.1.2. Using quotation marks, Boolean operators and wildcard

As suggested by dos Santos Gonçalves & Campos (2022) and Türkeli, et al. (2018), the search keywords integrated with the uses of quotation marks, Boolean operators and wildcard to increase the robustness of the search results. The quotation marks (" ") have been included for searching exact phrase to ensure the accuracy of conceptual keywords. While the Boolean operators "AND" and "OR" were used to allow different combinations of search keywords aims to maximize the search. Likewise, the wildcard "*" was used as right-hand truncation which allows searching the "root" form of a word with

all its different endings, for example, biodegrad* was used to retrieve "biodegradable", "biodegradation", "biodegrade" and so on.

2.1.3. Choosing the citation database

The WoS Core Collection was chosen as data collection source on the topic. It is noteworthy that WoS is well acknowledged as one of the most trusted global citation databases which abstracting and indexing peer-reviewed high-quality scientific and scholarly publications (dos Santos Gonçalves & Campos, 2022; Tseng, et al., 2019). It is widely used among academicians to collect sample data for bibliometric analysis in business research (Birkle, Pendlebury, Schnell & Adams, 2020; Khare & Jain, 2022). The WoS indexing databases include journals (e.g., Social Science Citation Index, Science Citation Index Expanded, Emerging Sources Citation Index, Arts and Humanities Citation Index, Current Chemical Reactions and Index Chemicus) conference proceedings (e.g., Conference Proceedings Citation Index), and books (e.g., Book Citation Index).. Despite WoS has been widely used, it also provides built-in analysis tools to produce representative figures, for example, analyse results and citation reports.

2.1.4. Inclusion and exclusion criteria

Inclusion and exclusion criteria were established to ensure the sample collected is reliable, consistent and objective manner. To gain insight into dynamic research productivity growth, the time span was not set. The search from the year when the first article in the field was published to date. To maximize the search results, all research areas were included as well as the type of documents, for example, articles, review articles, and conference proceeding papers were taken into consideration. All documents in other languages were excluded except the English language for collecting eligible and appropriate data to fulfil the study's objectives by conducting bibliometric analysis.

2.1.5. Final search query

A topic search on WoS core collection was conducted on 22 August 2022 by combining search keywords using quotation, Boolean operators and wildcard. The keywords search includes search in the title, abstract and keywords of the publication. The final search query as follows: (("circular econom*") or ("circularity")) and ("biodegrad*") and

(("consumer*") or ("user*") or ("customer*")). The search query and results for this study are represented in the Venn diagram below.
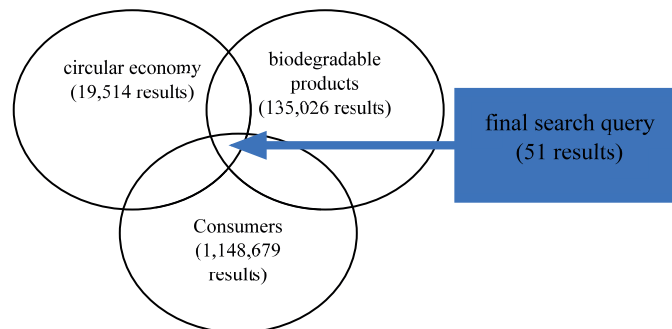
Figure 1: Venn diagram represents the search query of the scope in this study.

3. Data collection

The selected sample data of publication was exported and stored as Excel and tab-delimited text files. All the titles of publications were scanned through for checking eligibility.

3.1. Bibliometric analysis

3.1.1. Software and techniques

Various data presentation software tools, Tableau and VOSviewer were utilised in this study. Tableau Desktop (2022.1version) software was used for visualizing the productivity and citations, not limited to the type of documents, publication trends, cited analysis, most research areas and most productive journals.

VOSviewer was used as its effectiveness in graphical representation tools of network analysis. It is a free software, developed by Van Eck and Waltman from Leiden University, Netherlands. The advantages of VOSviewer are user-friendly for constructing and viewing bibliometric network, and ease of interpretation. A different unit of analysis was presented in VOSviewer to visualize the network relationships among the unit of analysis. Fractional counting was chosen because it is more accurate.

Each cluster represents different colours.

4. Results and Discussion

4.1. Document Type

A total of 51 documents were retrieved from the WoS Core Collection, it was found that 31 (60.8%) were journal articles, followed by 18 (35.3%) review articles and 2 (3.9%) conference proceedings. These documents were indexed in respective databases as presented in Table 1.

Web of Science Index	Document Type	
Conference Proceedings Citation Index - Science (CPCI-S)	Proceedings Paper	1
Emerging Sources Citation Index (ESCI)	Article	4
	Review	3
Science Citation Index Expanded (SCI-EXPANDED)	Article	18
	Article; Early Access	1
	Review	15
Science Citation Index Expanded (SCI-EXPANDED); Conference Proceedings Citation Index - Science (CPCI-S)	Article; Proceedings Paper	1
Science Citation Index Expanded (SCI-EXPANDED); Social Science Citation Index (SSCI)	Article	8

Figure 2: Distribution of the document type and Web of Science Indexing.

4.2. Research Area

The distribution of the research areas in Figure 2 illustrates the development stages in the research field. The top 5 research areas are *Environmental Sciences Ecology* (35.3%), *Science Technology Other Topics* (33.3%), *Engineering* (29.4%), *Chemistry* (23.5%) and *Material Science* (13.7%). These results revealed the majority of biodegradable studies in circular economy focused on environmental related issues, processes and material application.
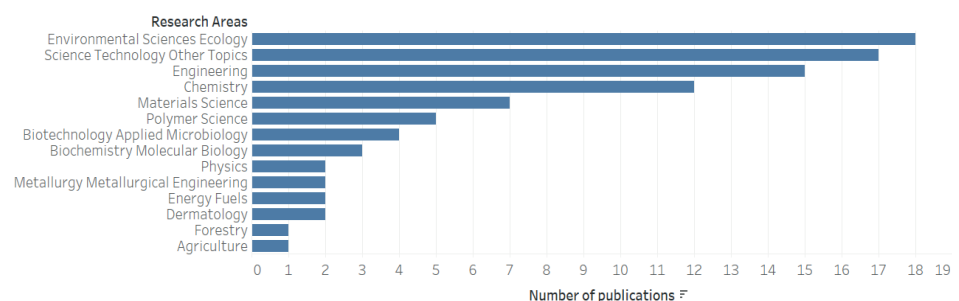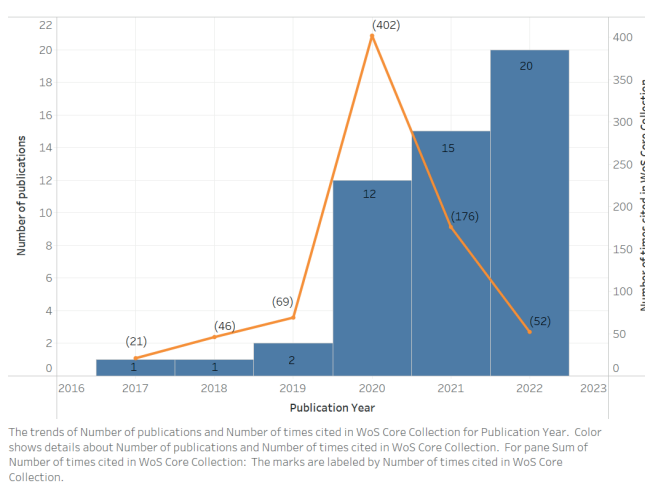

Figure 3: Distribution of the research areas.

4.3. Publication trend

The annual publications and sum of times cited in WoS Core Collection in Figure 3 clearly illustrate the development stages in the research field. The first article titled "Improving the 'tool box' for robust industrial enzymes" was published in 2017. This

study discussed using 'nature's catalysts', aimed to provide a sustainable and 'green chemistry' route to chemical synthesis without producing any harmful waste to our environment. This early publication focused on sustainable innovation, in particular biodegradable processes and materials related to applications. As seen in Figure 2, the research productivity is low, until 2020, the publications on the topic remained limited, e.g. less than 3 publications per year. The number of publications spike from 2 to 12, in 2019 and 2020, respectively.

To understand the trend of scientific production, the cited analysis was performed. It gives the number of times the publications have been cited by other publications listed in WoS Core Collection. Despite the publication is limited for the period 2017-2019, it was observed that the number of citations per year is increasing significantly, 21, 41 and 69 for the year 2017, 2018 and 2019, respectively. A remarkable note is that there were over 400 cited times for 12 publications in the year 2020. This momentum is mainly due to European Commission implemented policies and strategic plans adopting and moving to sustainable production and consumption in the region of European Union (EU). For examples are EU Plastic Strategy (2018) and EU Bioeconomy Strategy (2018), EU Green Deal (2019), and New EU Circular Economy Action Plan (2020). Under these new implementations, much efforts has been placed on the design and production of bio-based or biodegradable materials and products.

The trends of Number of publications and Number of times cited in WoS Core Collection for Publication Year. Color shows details about Number of publications and Number of times cited in WoS Core Collection. For pane Sum of Number of times cited in WoS Core Collection: The marks are labeled by Number of times cited in WoS Core Collection.

Figure 4: Annual publications and the sum of times cited in WoS.

4.4. Most productive authors and countries

Based on the data collected, a total of 223 authors were identified from 26 countries. The main contributors to the body of knowledge in the research area of biodegradable

related studies were from the US (17.6%), Italy (13.7%), England (13.7%), Poland (7.8%) and the Netherlands (7.8%). The top 20 main contributors' origin countries are presented in Figure 4. Out of 223 authors, four authors published more than one journal articles, e.g., Harris, Z. M., Kakadellis, S., Kovacevic, Z., and Morganti, P.
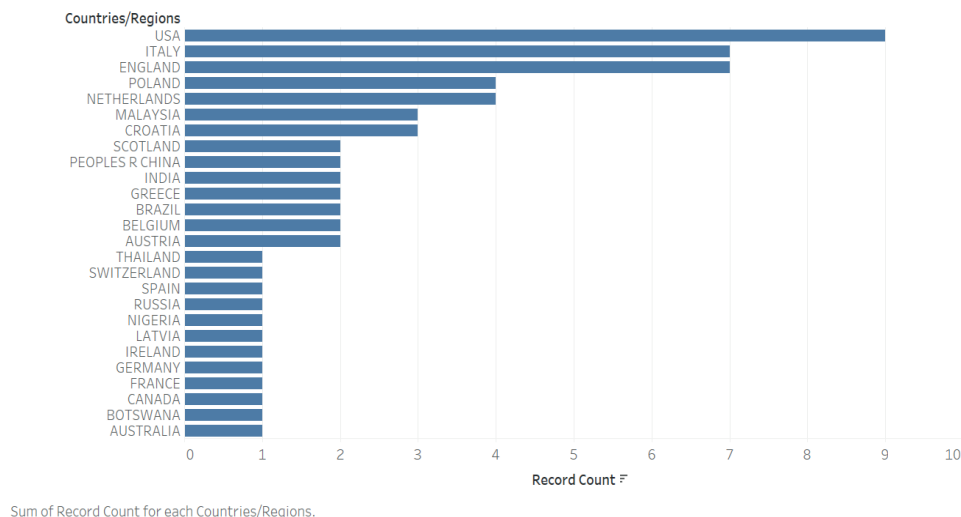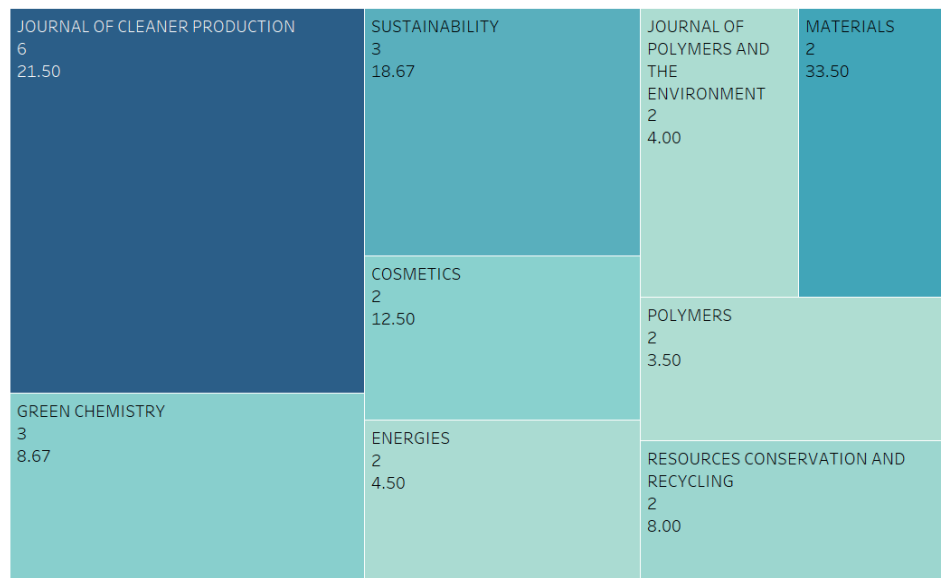

Figure 5: Top 20 authors' origin countries.

4.5. Most productive publication journals

The top productive publication journal with consideration more than two journal articles in particular publication journal as in Figure 5. Among publication journals, the *Journal of Cleaner Production* is the most popular and productive journal with 6 journal articles and the average times cited in WoS is 21.50, followed by *Sustainability* and *Green Chemistry* with 3 journal articles, and average times cited in WoS of 18.67 and 8.67, respectively.

4.6. Most influential works -- highly cited articles

The following analysis presented the top 3 highly cited journal articles with at least 50 times of cited, times of citation, yearly average cited, 5-year citations records. The most influential work is from Ramesh Kumar (2020) discussed the state-of-the-art, challenges and emerging trends in bio-based and biodegradable polymers with 111 times cited, on average of 37 times cited. It is notable that these top 3 publication titles are material related, "Current Opinion in Green and Sustainable Chemistry", "Material" and "Bioengineering Basel".

| JOURNAL OF CLEANER PRODUCTION 6 21.50 | SUSTAINABILITY 3 18.67 | JOURNAL OF POLYMERS AND THE ENVIRONMENT 2 4.00 | MATERIALS 2 33.50 |

| COSMETICS 2 12.50 | POLYMERS 2 3.50 |

| GREEN CHEMISTRY 3 8.67 | ENERGIES 2 4.50 | RESOURCES CONSERVATION AND RECYCLING 2 8.00 |

Source Title, Number of publications and average of Number of times cited in WoS Core Collection. Color shows sum of Number of times cited in WoS Core Collection. Size shows Number of publications. The marks are labeled by Source Title, Number of publications and average of Number of times cited in WoS Core Collection. The view is filtered on Number of publications, which ranges from 2 to 6.

Figure 6: Top productive publication journal.

4.7. Co-authorship network analysis of the author

Co-authorship is a form of association where two or more researchers agreed to collaborate and contribute to the content of the research topic. Co-authorship network analysis assesses the relationship between collaborators with respect to a different unit of analysis., such as authors, organizations, and countries. It maps the collaborators and measures the amount of collaboration.

The co-authorship network of authors that have co-authored at least one research paper as shown in Figure 6. A total of 223 authors with the greatest total link strength have been selected and grouped into 48 clusters. This resulting 526 links with a total link strength is 113. Each cluster represents different colours. The biggest cluster 1 is in red, and consists of 13 authors, followed by cluster 2 (green) and cluster 3 (blue), which consist of 10 authors each. For example, cluster 1 co-authored by Battista, F., Bolzonella, D., Cavinator, C., Eusebi, A. I., Fatone, F., Fino, D., Frison, N., Gottardo, M., Majone, M., Pavan, P., Tommasi, T., Valentino, F., and Zeppilli, M.

The co-authorship network of authors that have co-authored at least 2 research papers as shown in Figure 7. They are the top 4 out of 223 authors with at least 2 research papers, e.g., Harris, Z. M., Kakadellis, S., Kovacevic, Z., and Morganti, P.

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TABLE 1: Top 3 most influential works - highly cited articles (citations > 50).

| Rank	Authors (Year)	Title	Source Title	C	C/Y	2018	2019	2020	2021	2022
						5-year citations				
1	Ramesh Kumar et al. (2020)	Bio-based and biodegradable polymers - State-of-the-art, challenges and emerging trends	Current Opinion in Green and Sustainable Chemistry	111	37	0	0	18	51	42
2	Ncube et al. (2020)	Environmental Impact of Food Packaging Materials: A Review of Contemporary Development from Conventional Plastics to Polylactic Acid Based Materials	Materials	66	22	0	0	1	31	34
3	Mainardis et al.(2020)	Up-Flow Anaerobic Sludge Blanket (UASB) Technology for Energy Recovery: A Review on State-of-the-Art and Recent Technological Advances	Bioengineering Basel	55	18.33	0	0	5	28	22

C=Total citations; C/Y= Total citations per year

4.8. Co-authorship network analysis of countries

Figure 8 shows the co-authorship network of countries that have co-authored at least 1 research paper. A total of 26 countries with the greatest total link strength have been selected and grouped into 16 clusters. The total link strength is 10.50. Each cluster represents different colours. There are two biggest clusters consisting of 4 countries each. Red cluster (ie., Belgium, Brazil, British, and US) and green cluster (ie., India, Italy, China and Russia). Two clusters consist of 3 countries each: blue (ie., Botswana, Greece and Malaysia) and yellow (ie., Austria, Germany and Netherlands). The rest of the clusters do not connect to any countries. This shows lacking collaboration among countries and regions.
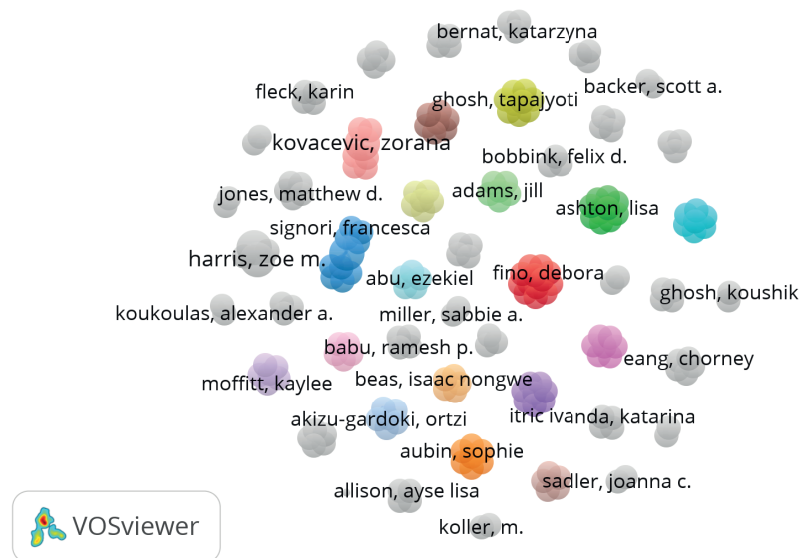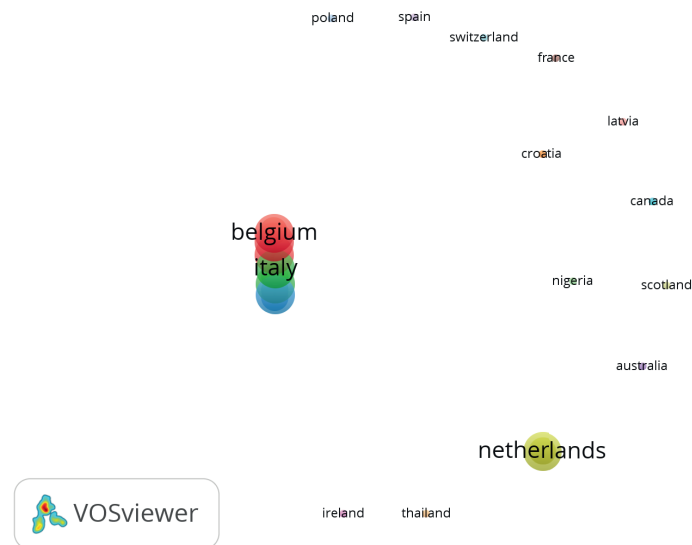
Figure 7: The co-authorship network of authors (at least 1 research paper).
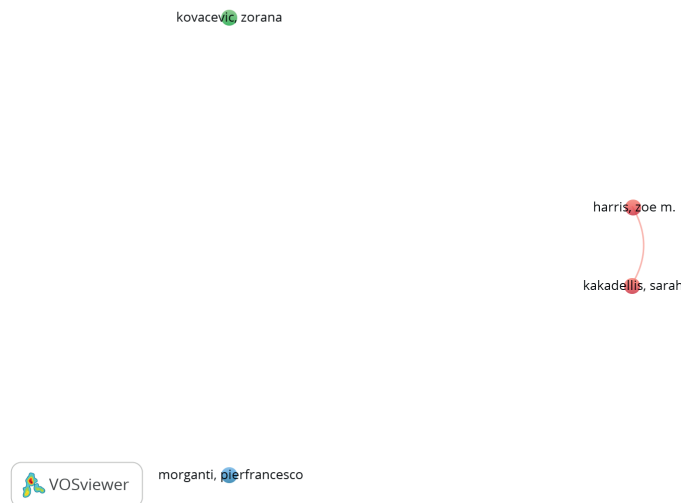
Figure 8: The co-authorship network of authors (at least 2 research papers).

4.9. Keyword co-occurrence network

Keywork co-occurrence network analysis was used to investigate the knowledge struc-ture of science fields. In VOSviewer, "All keywords" is set as the default option as the unit of analysis for keyword co-occurrence. These include "Author keywords" and "KeyWords Plus". There are distinct, author keywords reflecting the content of the article. Commonly authors would identify 3-5 important words in their articles. On the other hand, Keywords plus is not inclusively representing the content of the articles.

Figure 9: The co-authorship network of countries.

To gain a realistic insight in the knowledge structure, "Author keywords" was selected as a unit of analysis and set the threshold with a keyword that appeared with frequency ≥ 3 in the selected research papers. Only 9 of 214 keywords meet the threshold and are grouped into 3 clusters. This resulting 20 links with a total link strength of 18.5.

Figure 9 shows 3 clusters formed in the keyword co-occurrence network. Themes for each cluster were identified: Cluster 1 – the process of biodegradation, Cluster 2 – consumer perception and environmental impact, and Cluster 3 – biodegradable material.

5. Conclusion and Discussion

By using a bibliometric analysis approach, this study attempts to illustrate the development of the research in biodegradable studies in circular economy in different stages. In general, it can be divided into two stages: production and consumption. In the early stage, research mainly focused on production which is the development of biodegradable processes and biodegradable materials or products. The later research focused on consumption, however, still lacking. Therefore, attitudes and perceptions toward consumption as newly emerging dimensions for future agendas in the field of the study have been identified.
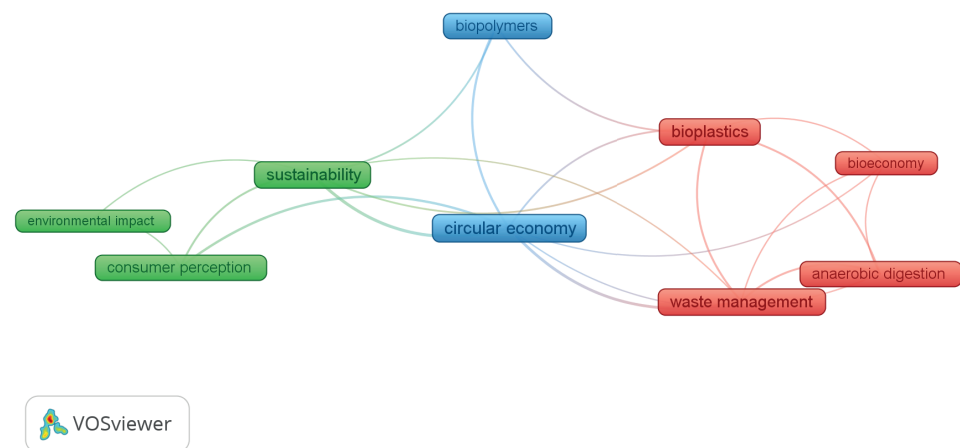
Figure 10: Keywork co-occurrence network analysis (Author keywords).

The research areas revealed the majority of biodegradable studies in circular economy focused on environmental related issues, process and material application. This is not surprising as both theoretical and practical levels of CE are mainly rooted in environmental science ecology, integrated with technological innovation in engineering and chemistry to produce biodegradable products. Most influential publications mainly focused on the production of biodegradable material. The network analysis of co-authorship for both authors and countries illustrates that the collaborations are minimal. Based on the keywork co-occurrence network analysis, three themes were identified: biodegradable process, biodegradable materials and consumers' perception of biodegradable products.

As with other academic studies, this paper also has some limitations. The bibliometric data was retrieved from a single database source, e.g., Web of Science. Multiple database sources should be considered for future studies to generalise the results holistically. Additionally, inclusion and exclusion criteria could be more stringent, in particular, in business and management research, high quality peer-reviewed publications in ABDC journal quality list might taking into consideration in future studies.

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