

Circular economy and sustainable practices in the food industry: A comprehensive bibliometric analysis

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ABSTRACT

The United Nation's Sustainable Development Goals (SDGs) prioritize halving global per capita food waste at retail, consumer, production, and food supply chain by 2030. This aligns with promoting circular economy principles for enhanced sustainability. The circular economy offers a transformative approach to the food industry by promoting environmental health, human well-being, and economic prosperity. This bibliometric analysis examines how circular economy principles can drive sustainability in food businesses, which closely aligning with SDGs 12.3 (food waste reduction), 12.5 (waste reduction), 13.2 (climate policy integration), and 13.3 (climate adaptation). Through a bibliometric analysis of 1000 relevant articles sourced from the Web of Science (spanning from 2005 to 2023), we evaluated the progress, challenges, and opportunities in this field. Utilizing analytical tools such as Biblioshiny (Bibliometrix) package of R-Studio and VOSviewer, the researchers identify key trends and research hotspots through thematic maps, co-occurrence networks, co-citation analysis, keyword analysis, and collaboration networks. This research highlights that the circular economy can transform the food industry by implementing sustainable waste management practices, optimizing supply chains and resource utilization to minimize environmental impact. Furthermore, research findings indicate that adopting circular economy principles in the food industry can significantly reduce waste and enhance resource efficiency by transforming food waste into valuable products such as biogas and bio-based materials. This study provides valuable insights for researchers, practitioners, policymakers, and government officials to improve sustainable food production systems. It enhances understanding in a vital area for guiding future endeavours to promote circular economy strategies for a more sustainable and efficient food industry.

1. Introduction

The transition towards a sustainable and circular economy (CE) has garnered significant attention in recent years, particularly within the food industry. The food industry is an ideal sector to initiate this transition due to its high resource consumption and significant contribution to global waste generation. However, food waste, resource scarcity, and environmental degradation are some of the worldwide challenges that significantly impact the food production system globally. Research scholars like Yontar (2023); Jabbour et al. (2023); Abbate et al. (2023); Diéguez-Santana et al. (2022) indicated that the potential development of agriculture and food manufacturing can be ensured and maintained by the utilization of a circular economy perspective, especially in the food sector. In this pertinent, the scholars also suggested that resource

utilization, waste reduction, and sustainable development are the goals of the circular economy strategy. A key component of the goals of the European Green Deal through the circular economy (CE) process is obtaining zero carbon emissions by the year 2050. Thus, CE can be viewed as a flow of different materials and energy occurring in three circular layers (i.e., production, distribution, and consumption). The food industry needs to adopt a circular economy concept to create a closed system that successfully manages food waste and losses in the production, distribution, and consumption process.

Furthermore, circular economy and sustainable practices within the food industry plays a vital role in advancing sustainable food production systems and resilient agricultural practices. This directly aligns with the objectives outlined in Sustainable Development Goals (SDG) 12 and 13. SDG 12, Responsible Consumption and Production, aims to halve per

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capita global food waste by 2030 (Target 12.3) and significantly reduce waste generation through prevention, reduction, recycling, and reuse (Target 12.5). By adhering to circular economy principles such as waste minimization, recycling, and resource optimization throughout the food supply chain, research contributes to promoting responsible consumption and production practices (Rabbi et al., 2021). Additionally, SDG 13, Climate Action, emphasizes addressing climate change by enhancing education, awareness, and capacity-building (Target 13.3) and integrating climate change measures into national policies and planning (Target 13.2). Implementing circular economy principles in the food industry helps mitigate climate change by reducing greenhouse gas emissions, optimizing energy usage, and minimizing environmental impacts associated with food production and distribution (Doni et al., 2020).

Moreover, using circular economy concepts can lead to long-term production and supply chain, as well as new ways to create a better food system for the planet. It also enables people to use less energy and helps reduce greenhouse gas emissions by minimizing pollution and resources. Applying circular economy concepts to food production is critical to reducing waste, using resources more efficiently, and ultimately achieving the Sustainable Development Goals. The CE approach will further help the economy and the environment by allowing healthy products made from food waste to reach new consumers. Recently, several researchers (for instance, Kumar et al., 2023; Knäble et al., 2022; Patyal et al., 2022) have tried to uncover the relationship between CE values and sustainable development. The authors further emphasized that over the past few years, many more scientific papers have also been published in this particular field of science. The notable point of the studies in CE related to the food industry is that food engineers and manufacturers are trying their best to reuse, recycle, repair, and usage of less natural resources in their food production process (Gonçalves and Maximo, 2023; Reslan et al., 2022). Several eco-industrial parks have also been created by food engineers who make good use of the concepts of industrial ecology and symbiosis (Abu-Qdais and Kurbatova, 2022). On the other hand, economics and management studies highlighted how to integrate the concepts of sustainable development (SD) and circular economy (CE) at different levels (Antonoli et al., 2022). However, market and financial benefit-oriented approaches to the circular economy have also been explored by some other researchers (such as, Abbate et al., 2023; Ramos et al., 2022; Cuesta-Gonzalez and Morales-García, 2022).

Implementing a circular economy enables more effective use of resources and less waste throughout a product's entire life cycle, from manufacture to consumption (Bigdeloo et al., 2021). An integral aspect of food manufacturing, farming, and food trading contributes to the expansion of rural regions and can potentially promote adopting eco-friendly practices (Sgroi, 2022). According to Abbate et al. (2023), the conception of a circular economy might assist the environment by cutting down on carbon emissions when it comes to manufacturing food products. Encouraging consumers to buy through a closed value chain process and the circular economy is the most compelling aspect (Eisenreich et al., 2022). In this pertinent, Szűcs et al. (2017) indicated the utmost desire to overcome the difficulties that food processors face in obtaining necessary inputs and long-term collaboration among the farmers, intermediary agencies, and food processing companies. The scholars suggested that sustainable manufacturing procedures, less waste, and optimal use of resources can contribute to a food company's circular economy strategy. Thus, the abovementioned discussion implies that a circular economy system may bring a profitable and environmentally friendly economy to the food sector of any nation.

Previous scholarly articles demonstrate that several factors contribute to promoting CE and sustainability within the food sector. For instance, Fogarassy et al. (2020) revealed that individuals who are young, well-educated, environmentally concerned, and who reside in urban areas, as seen by their preference for purchasing organic food, have a higher propensity to participate in a circular system. Based on the

findings of Mehmood et al. (2021), the primary motivators for adopting CE methods within the agri-food supply chain included environmental, policy, economic, and financial advantages. However, the main obstacles to implementing the CE approach are associated with institutional, financial, and technical risks. In their research, Máté et al. (2022) proved that food manufacturing enterprises that are using viable and sustainable practices have higher levels of profitability. Besides that, the scholars suggested that ecological and economic aspects reinforce the beneficial influence of the social component on food corporate profitability. In another similar research, Jurgilevich et al. (2016) explored the issues and possible solutions for the production stage, consumption stage, food waste, and excess management, and how to overcome the challenges related to the transition towards a circular food system. In addition, the research of Jurgilevich et al. (2016) indicated that consumer behavior, policy, economics, financial incentives, and a commitment to social, ecological, and economic considerations are the key drivers of the circular economy and sustainability within the food industry.

However, the food industry faces significant challenges in achieving sustainability, with concerns about food waste, resource depletion, and climate change demanding innovative solutions. While prior research has extensively explored individual aspects of sustainability and waste management (Awino and Apitz, 2024; Wei et al., 2024). Furthermore, present studies focus on specific areas such as food waste reduction (Garg et al., 2024; Lehtokunnas, 2023), resource efficiency (Li et al., 2024; Ramanauskė et al., 2023), or technological advancements in waste processing (Ji et al., 2024; Rossi et al., 2024). This fragmented approach fails to address the complexity of sustainability issues within the food system. Additionally, limited research bridges these individual efforts to create a synergistic and holistic approach encompassing the social, economic, and environmental aspects within a sustainable framework (Garg et al., 2024; Vann Yarson et al., 2024). A significant gap exists in the literature concerning a detailed and systematic examination of the alignment between regional research priorities on circular economy and sustainable practices in the food industry with specific Sustainable Development Goals 12 (Sustainable Consumption and Production) and 13 (Climate Action).

Addressing this gap is crucial for advancing Sustainable Development Goals (SDGs) 12 and 13, which emphasize responsible consumption and production patterns, and urgent action to combat climate change and its impacts. This study contributes to an integrated research framework to address these gaps by employing a robust bibliometric analysis within a sustainable context.

The following questions guide our investigation: RQ1. What does the current academic research landscape look like regarding the circular economy and sustainable practices in the food industry? RQ2. How do research focuses differ across regions, and what does this say about global interest in sustainable food systems? and RQ3. What keywords and themes are prevalent in existing literature, and how do they relate to Sustainable Development Goals (SDGs) 12 and 13?

To address the research questions, this study aims to achieve several objectives: OBJ1. bibliometric analysis will be utilized to uncover trends in publications, highlight key research areas, and map the geographical distribution of research activity, OBJ1. it will explore how research focus varies by region, compare publication volumes across different areas, and interpret these differences to gauge global interest and identify regional challenges in food system sustainability, and OBJ3. the study will conduct a keyword analysis to pinpoint dominant themes and their interconnections, and evaluate how these themes align with specific targets within Sustainable Development Goals (SDGs) 12 (responsible consumption and production) and 13 (climate action).

This paper is organized as follows: following the introduction, we presented the methodology and bibliometric results, including: (1) descriptive statistics of publications, (2) the leading countries, influential authors, journals, and keywords within the realm of circular economy and sustainable practices in the food industry, and (3) thematic

categorization to identify emerging and declining research trends. Following this, we delineate pivotal considerations for shaping a research agenda, incorporating discussions, proposed recommendations, and conclusions with key contributions.

2. Methodology

In order to evaluate the effects, quality, and quantity of investigations on food sustainability within the framework of a circular economy, this study used bibliometric analysis. Understanding the subject's thoughtful, conceptual, theoretical, and social perspectives, it was possible to apply the bibliometric methods of analysis in the present investigation. In this regard, the researcher followed the prior study method of Kristia et al. (2023), Rojas-Sánchez et al. (2023), and Zapata-Mendoza et al. (2022) as they all used bibliometric methodologies in

their systematic literature review framework to represent quantitative data generated from a large number of journal articles from any core collection of databases. In this regard, Linnenluecke et al. (2020) suggested bibliometric analysis in case of conducting literature review-based research. In addition to bibliometric methods, this study employed K-structure analysis based on the availability of the literature of the established scientific community in order to map and illustrate the intellectuality, conception-basis, and social K-structure. The intellectual framework consists of the main sources, citations, and references that convinced the present researchers to conceptualize and develop the present research's highlighting discipline. A conceptual framework is a structure that outlines the key elements and their relationships within a specific research topic. The social structure of a given situation consists of the most influential individuals and groups of researchers who collect and share knowledge, thereby intending to conduct collaborative

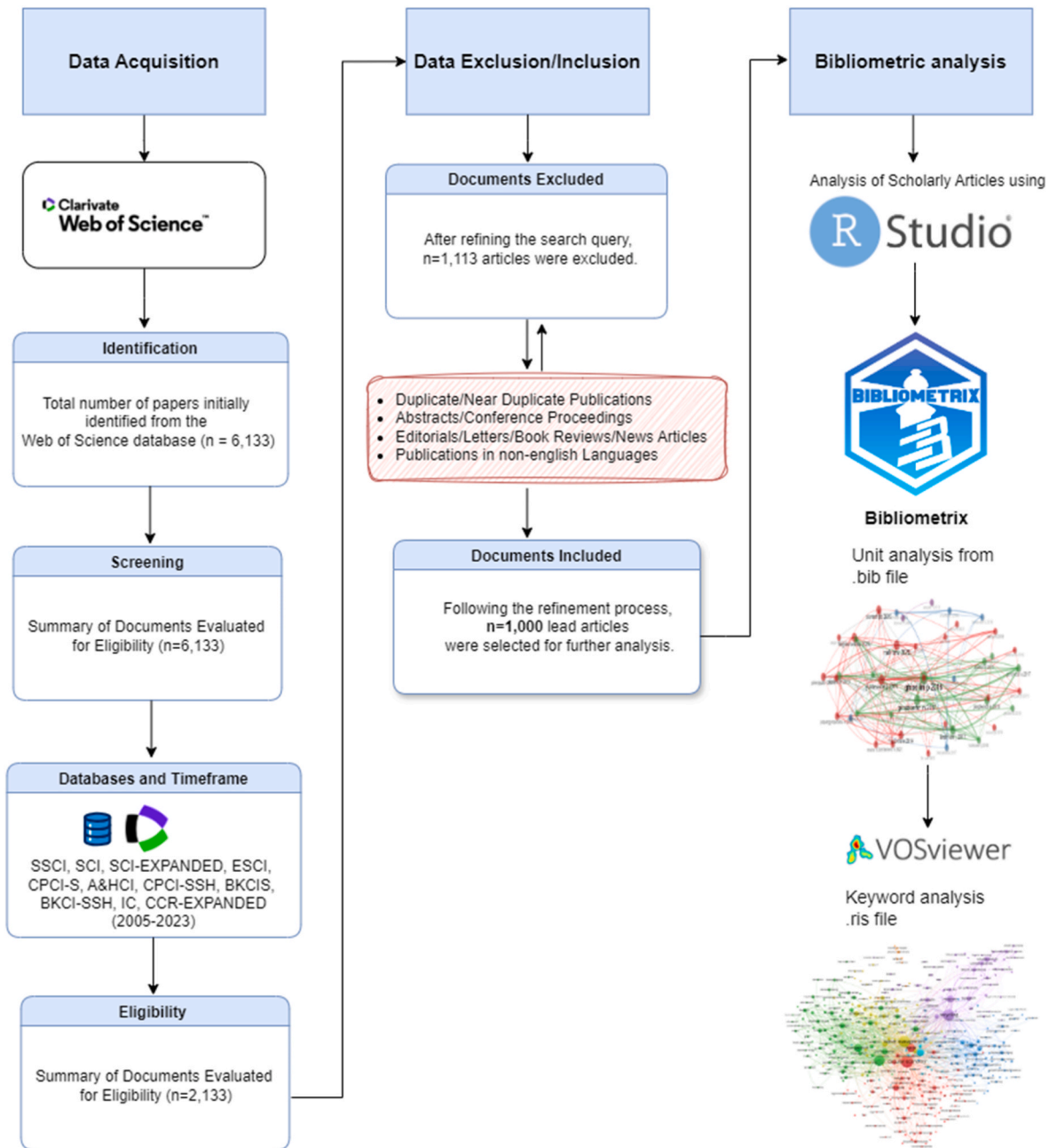


Fig. 1. Research process, methods, and instrument. Source(s): Authors own work.

research.

The bibliometric review was performed using the bibliometrix package in R-Studio (version 4.3.2). This approach enabled the mapping and exploration of food production sub-themes that are crucial for responsible consumption and production, and climate action sub-themes as part of a circular economy platform. Notably, bibliometric reviews offer a faster and more efficient way to analyze vast amounts of literature compared to traditional methods of manually reviewing books (Malatesta et al., 2023; Gonçalves et al., 2022; Mejia et al., 2021). The following Fig. 1 represents the research methods, process, and instruments used in this study.

2.1. Data selection/search approach

This study employed advanced bibliometric software tools from the popular R package 'Bibliometrix' for providing functionalities, and its user-friendly interface 'Biblioshiny', to conduct the bibliometric analysis. This study utilized bibliographic data retrieved from the Web of Science (WoS) database. Web of Science (WoS) was preferably selected over other databases like Google Scholar or Scopus due to its exceptional quality and comprehensiveness. WoS database has been utilized by numerous researchers in prior studies (Goyal et al., 2021; Ren et al., 2023; Tang et al., 2023). Its curated database, ensured by rigorous selection criteria, guarantees highly reliable data, and fosters accurate citation metrics and bibliometric analyses. WoS's strengths extend beyond data accuracy. Specialized tools empower researchers with advanced functionalities for research evaluation, while strong community recognition reinforces the value of findings published in WoS-indexed journals. Initially, our search identified 6133 publications from 2005 to 2023. For collecting published articles for this research from the database, a rigorous searching process was used by the terms "OR" to include synonyms for both phrases and an "AND" for combining the sets of similar kinds of words for both the main search topics. By utilizing the advanced search option in the Web of Science (WOS) database, the following keywords were employed: TS=("circular economy" OR "CE" OR "circular production") AND ("food industry" OR "sustainable food industry"). Limited by: DOCUMENT TYPES: (ARTICLE OR REVIEWS) AND [excluding] PUBLICATION YEARS: 2023, years of publication span: 2005–2023. The articles were selected based on the following indexes: SSCI, SCI, SCI-EXPANDED, ESCI, CPCI-S, A&HCI, CPCI-SSH, BKCI, BKCI-SSH, IC, CCR-EXPANDED. After refining the search query, 2133 articles were identified for further analysis on November 11, 2023.

The search, conducted in the Web of Science database and adhering to the specified exclusion criteria, aimed to comprehensively gather relevant literature within the given timeframe. To maintain the focus and quality of our research, we excluded total 1133 articles. Specifically, $n = 90$ duplicate articles were identified and removed to prevent over-representation of certain studies due to their indexing in various databases. Non-English $n = 136$ articles also excluded for ensuring consistent understanding and analysis. Additionally, $n = 54$ non-research articles such as editorials, letters, and book reviews were excluded to focus on empirical research that provided data and/or observations for our analysis.

Furthermore, $n = 136$ articles were excluded based on publication date to ensure the literature reviewed remained relevant and current to our research question. In addition, $n = 41$ studies, including reviews and case studies, were excluded for not aligning with our research objectives, which focused on surveys, experiments, and specific analyses. To maintain subject relevance $n = 649$ articles outside our specific topic were excluded for ensuring the information remained pertinent. Lastly, $n = 27$ articles were excluded for lacking crucial data to ensure the validity of our results by using complete datasets. By applying these exclusion criteria, researchers selected 1000 relevant, high-quality, and focused articles for the study.

Afterward, the 1000 literature records have been transferred to files

in '.bib', '.xls', and '.txt' formats, along with the 'title', 'abstract', 'keywords', 'citation details', and 'bibliographic data'. The dataset was imported into R-Studio using the Bibliometrix package to conduct thematic trend analysis and bibliometric analysis. The data was subsequently entered into VOSviewer software for keyword extraction and analysis.

2.2. Biblioshiny (R-studio software)

Biblioshiny is an interactive tool developed in R-Studio software specifically designed for bibliometric research. Its user-friendly interface has made it a popular choice among researchers, as evidenced by its use in many prior studies to analyze scholarly literature (Kristia et al., 2023; Linnenluecke et al., 2020; Aria and Cuccurullo, 2017). This software can extract bibliographic data from multiple data sources, such as Scopus, Web of Science, SCOPUS, and Dimensions. As a result, the Biblioshiny, built on the Bibliometrix R package, provided access to a wide range of analyses, such as annual scientific output, most cited articles, additional important sources, most significant authors and affiliations, geography, and keyword cloud generation.

2.3. VOSviewer software

VOSviewer, a widely used bibliometric tool, enables users to generate detailed bibliometric networks of various diversified entities, including authors, academics, institutions, collaborative nations, regions, and continents (Mejia et al., 2021; Van Eck and Waltman, 2010). This approach enables the utilization of various methods for research collaboration and network analysis, including keyword co-occurrence, bibliographic pairing, co-citation, and joint or co-authorship. However, to determine the significance of the research domain, we employed "keyword analysis" in this study.

3. Result and analysis

3.1. Descriptive statistical data

Table 1 exhibits data on articles published between 2005 and 2023, retrieved from the WoS database. A total of 6133 papers were initially identified; however, this number was narrowed down to 1000 publications (among those, 974 were research articles, 25 book chapters, and 1 early access review) that were published in 459 journals. These publications collectively utilized 5947 numbers of 'keywords' and 3455 keywords related to the author. The mean number of citations per article is 195.8. Articles about the sustainable food sector and the circular economy have a high percentage of international co-authorships (41%). On the other hand, the annual growth rate in this domain is 3.78%,

Table 1
Descriptive statistical data regarding the compilation.

Description	Results
Articles	1000
Timespan	2005–2023
Sources (Journals, Books, etc)	459
Annual Growth Rate %	–3.78
Article's Average Age	5.2
Average citations per article	195.8
References	126782
Keywords Plus (ID)	5947
Author's Keywords (DE)	3455
Authors	4106
Single-authored articles	69
Co-Authors per articles	4.53
International co-authorships %	41
Research articles	974
review; book chapter	25
review; early access	1

indicating a downward trend. However, Table 1 for this study is presented below.

3.2. Countries with high levels of productivity and collaborative efforts

Table 2 illustrates the cumulative number of publications for the majority of the top 10 countries, which represents 65% of the total number of papers. The distribution of research contributions for the circular economy study was the following: the USA accounted for around 35%, the UK contributed 10%, China contributed 8%, and Italy contributed 5%. These percentages indicate that each country displayed a significant inclination towards international collaboration in the studies that were concentrated on circular economy.

However, Fig. 2 in this study represents the top 20 countries of the corresponding authors. This figure shows the number of documents from 20 different countries by corresponding authors, with two types of collaborations: single-country publications (SCP) and multiple-country publications (MCP).

In addition, Fig. 2 shows that the USA has the highest number of publications, followed by the United Kingdom and China. It also shows that most countries have more SCP than MCP, except for China, India, and Malaysia, which have more MCP than SCP. This figure suggests that the USA, the United Kingdom, and China are the most productive and influential countries in the field of circular economy and that they have different patterns of collaboration with other countries. It also suggests that some countries, such as China, India, and Malaysia, are more involved in international collaboration than others.

3.3. Keyword analysis

Researchers utilize keywords to provide a precise representation of any specific study subject or research topic. A keyword analysis is an effective bibliometric research technique for detecting prevalent subjects and patterns within the study area. In this study, the selected publications in the field of circular economy and sustainable food business were further examined using bibliometric methodology, with a specific emphasis on frequently recurring keywords. In the Web of Science database, two distinct types of keywords were customized: "author's keywords" and "keywords plus." To clarify, "keywords plus" represents the terms or phrases often found in the references cited in an article but are not included in the article's title. The results of this study are presented in the form of word clouds.

Fig. 3 displays a network visualization showing how frequently authors' keywords appear together in academic publications. Each node in the network represents a keyword, and the connections between them indicate that these keywords were mentioned in the same article. Larger nodes signify more frequently used keywords, while different colors represent distinct thematic groups. Cluster 1 (in red colour) centers around the concepts of "circular economy" and "food waste," highlighting research focused on sustainable practices within the food

Table 2
Top 10 publishing countries based on identical trends in authors and collaborations.

Rank	Country	Articles	SCP	MCP
1	USA	187	135	52
2	United Kingdom	99	51	48
3	China	88	47	41
4	Italy	71	47	24
5	Germany	42	24	18
6	Spain	40	21	19
7	France	37	26	11
8	India	33	21	12
9	Australia	30	15	15
10	Canada	29	20	9

Note: SCP: Single country publications, and MCP: Multiple country publications.

industry. Keywords like "biomass," "anaerobic digestion," and "bio-refinery" point to topics concerning the transformation of food waste into valuable products. This reflects an emphasis on turning waste into resources, aligning with circular economy principles. However, Cluster 2 (in green colour) spins around themes of "waste management" and "sustainable development." It includes keywords related to policy, implementation, and challenges in managing waste sustainably. This cluster indicates a significant amount of research aimed at improving waste management practices and policies.

In the Cluster 3 (in purple colour), keywords like "recycling" and "recovery" dominate, showing a focus on recovering materials, especially from electronic waste. Terms such as "lithium-ion batteries," "cathode materials," and "electronic waste" suggest that this research is concerned with the recovery of valuable materials from used products. In addition, Cluster 4 (in blue colour) cluster highlights "pyrolysis" and "degradation," pointing to studies on chemical recycling processes and the breakdown of materials, particularly plastics. This indicates an interest in developing methods to manage plastic waste through chemical processes.

Furthermore, the Cluster 5 (in yellow colour) emphasizes broader sustainability issues with keywords like "environment," "climate change," and "renewable energy." This shows a focus on environmental impacts and the role of renewable energy in sustainability efforts.

The relevance of these findings to the circular economy and sustainability practices in the food industry is significant. The red cluster emphasizes the transformation of food waste into renewable energy or valuable by-products, which supports the principles of the circular economy by reducing waste and creating economic value.

Sustainability practices in the food industry are further highlighted by keywords in the green cluster, such as "supply chain," "quality," and "agriculture." These terms suggest a focus on improving sustainability across the food production and consumption lifecycle, from optimizing resource use to ensuring sustainable agricultural practices.

However, these findings align closely with the goals of SDG-12, which aims for responsible consumption and production. The emphasis on waste reduction, efficient resource use, and sustainable production practices directly supports the targets of SDG-12, particularly in minimizing food waste and reducing losses along production and supply chains.

Additionally, the yellow cluster's focus on "climate change," "renewable energy," and "emissions" underscores the connection between sustainability practices and climate action, aligning with SDG-13. Efforts to reduce greenhouse gas emissions and promote renewable energy sources are critical for combating climate change, and sustainable waste management practices contribute to this goal by decreasing methane emissions from landfills.

The word clouds mostly revolved around often-discussed topics such as circular economy, waste management, recycling, climate change, performance, mechanical qualities, and food waste. However, the following Fig. 4 shows the word clouds containing the 30 most frequently occurring keywords plus.

In this study, there are some core research investigation areas highlighted from Wordcloud (Fig. 4), i.e., circular economy, sustainability, life-cycle assessment, management, recovery degradation, municipal solid waste, recycling, food waste, supply chain, and food packaging. The 426 most frequent authors' keywords were classified into seven different clusters coded in different colors. Publications mentioning the circular economy often included the following terms, as seen in Figs. 3 and 4. There are a total of 1122 links in 7 clusters, with a strength of 19,388.

3.4. Conceptual structure

The conceptual framework provides a concise overview of the primary subjects related to a particular area or discipline (Aparicio et al., 2019). The examination of the conceptual structure may be approached

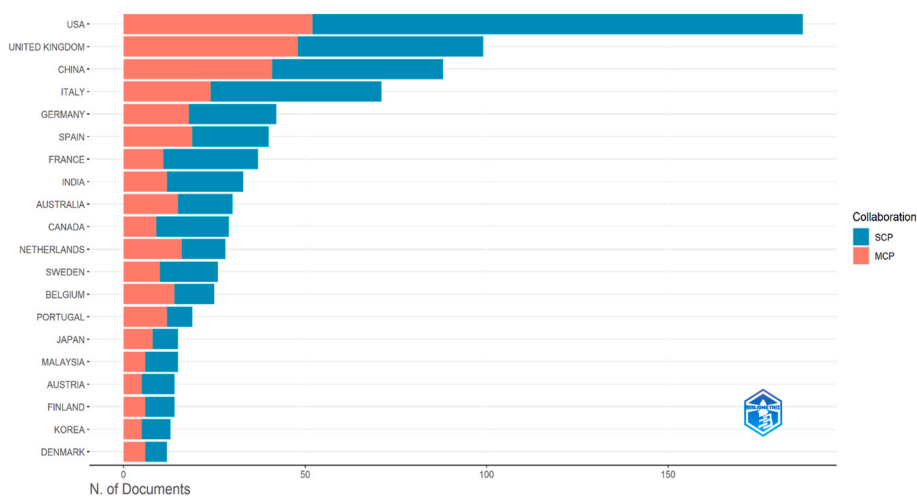


Fig. 2. Top 20 Countries of the corresponding author. Note: SCP: Single country publications, and MCP: Multiple country publications.

using several analytical methods, such as the analysis of “co-occurrence networks,” the creation of “theme maps,” and the investigation of “thematic progression.” The primary objective of this conceptual framework is to ascertain the relative closeness between various research subjects, discover research clusters that are in high demand or have not been extensively studied, and analyze the temporal patterns of research themes.

3.4.1. Co-occurrence network

Topics that have a frequent recurrence in the ‘title,’ ‘abstract,’ or ‘keywords’ of numerous studies are considered to exhibit close co-occurrence. The following Fig. 5 illustrates the co-occurrence network of the author keywords that were most often used in the articles examined for the purpose of this research.

Using the walking clustering method, the hybrid network map presented in this study (Fig. 5) visualizes the research connections, normalizes them, and automatically adjusts the network. From the results of joint network visualization, it can be said that CE and related subjects consist of different groups. The first cluster contains green nodes that represent management. The second cluster is about sustainability, the third is about food waste, the fourth is about challenges, the fifth is about life cycle assessment, and the sixth is about different colour outcomes. In case of clarification, a thick green line existed between the circular economy and food management. In the blue cluster, food waste management and circular economy ideas are often linked (Mathews, 2020). Sustainable development studies (Patyal et al., 2022), challenge issues (Balasescu and Seguin, 2018), circular economy by-products (Manaf et al., 2021; Somoza-Tornos et al., 2021), and life cycle measurement (Basile et al., 2021; Ünal and Shao, 2019) were presented in the network for comparison.

The author’s keyword analysis of the article database shows that sustainability (27 times) appears slightly more in comparison to food waste (06 times), whereas economy was the minimum (05 times). Various authors used circular (04), bio-active compounds (04), agriculture (03), by-products (03), and drivers (03) as the keywords in this field. The use of sustainability aligns with the principles of the circular economy, whereby food waste is found to be a substantial concern in this research area (Burg et al., 2023; Matheri et al., 2023). Moreover, the areas of bio-active compounds, agriculture, by-products, and food production drivers aimed to foster the advancement of circular economy practices (Koytsoumpa et al., 2021). Therefore, the following Fig. 6 of this research shows the most relevant academic journals and publishing sources produced over the time frame.

In addition to the previously mentioned subjects, the cluster encompasses the subsequent academic journals or sources of publication

from 2005 to 2023: *Sustainability* (131), *Energies* (28), *Polymers* (28), *Journal of Cleaner Production* (25), *Foods* (20), *Materials* (20), *Resources Conservation and Recycling* (20), *Environmental science and pollution research* (19), and *International Journal of environmental research* (19). Based on the provided data, the ‘*Sustainability*’ journal occupies the topmost position with the highest number of publications in the field of CE connected to the food industry. Following that, the ‘*Energies*’ and ‘*Polymers*’ secures the second position, while the “*Journal of Cleaner Production*” journal ranks third.

3.4.2. Thematic map

Thematic map analysis facilitates writers to graphically depict prominent topics, assess the degree of subject associations, and identify patterns and trends. The thematic map in this part comprises topics that have been derived from the keywords given by the authors. The following Fig. 7 displays a thematic map consisting of four quadrants, each demonstrating a noticeable level of topic density and centrality.

The theme quadrant, identified as the basic quadrant, is constituted by research topics with a significant level of centrality but does not exhibit a significantly high density. Based on the thematic map (Fig. 7), the analysis of the 1000 selected articles during this time reveals the presence of four distinct research topics. The notable point is that there are a total number of 4106 authors identified who contributed to various themes: waste management challenges, biomass, dietary fibre, phenolic compounds, life-cycle assessment, sustainability, anaerobic digestion, agriculture, emissions, water, supply chain, bioethanol production, functional properties, acid conversion, and wastewater. Among these, seven were considered motor themes (waste management challenges, biomass, dietary fibre, phenolic compound, life-cycle assessment, sustainability, anaerobic digestion); three were in the nice theme (agriculture, emissions, water), five were emerging or declining (supply chain, bioethanol production, functional properties, acid conversion, wastewater), and finally, one was considered basic (acid conversion). The performance metrics of each theme emphasize two significant themes: anaerobic digestion, which embodies the circular economy theme, and waste management challenges. Its life-cycle assessment and sustainability serve as the industry’s fundamental themes for sustainable food production. Motor themes attain a high impact rate in comparison with the remaining themes.

3.5. Intellectual structure

The application of intellectual structure analysis permits researchers to visually depict the associations and arrangements among distinct constituents within a particular realm of understanding. In this specific

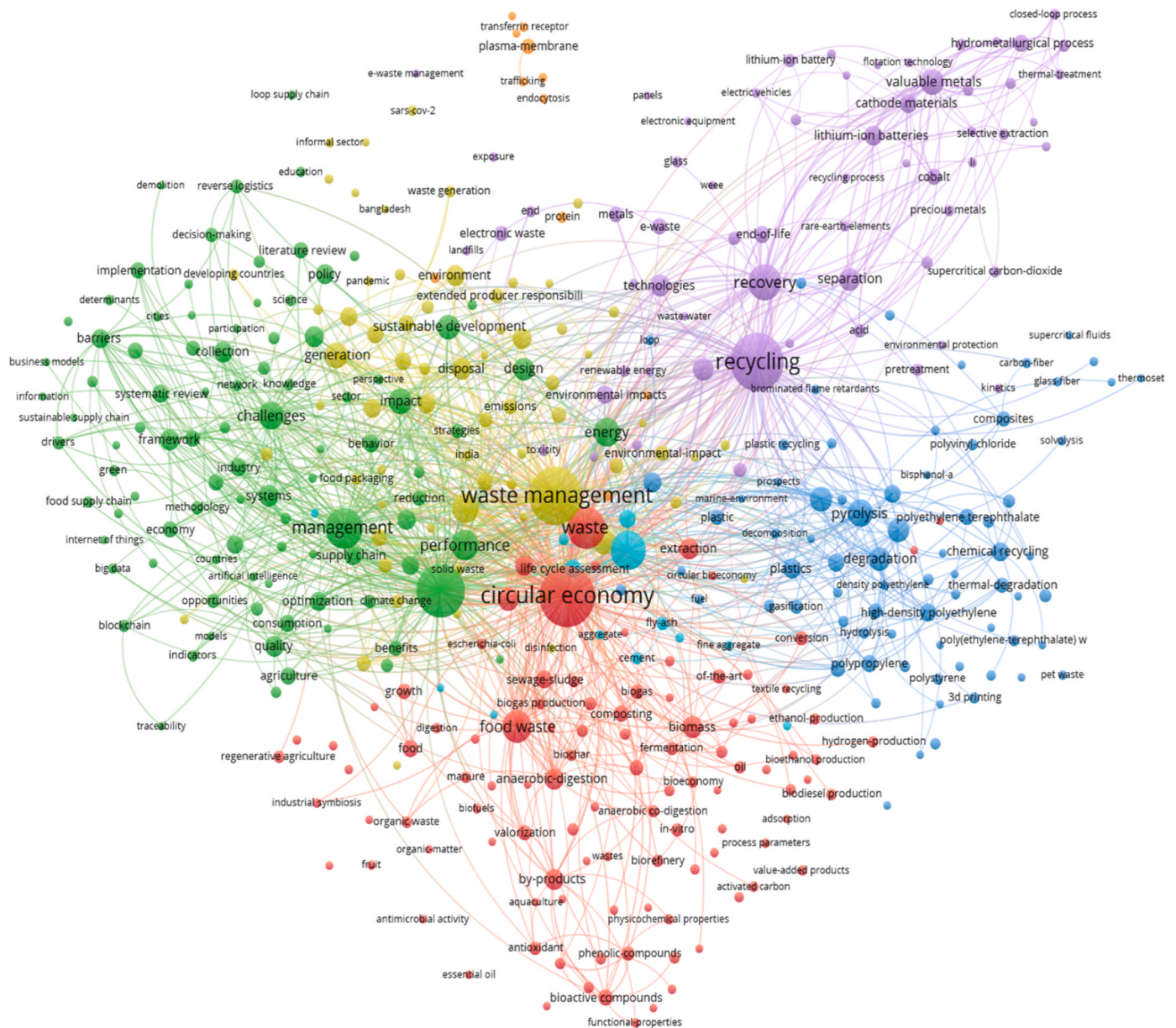


Fig. 3. The co-occurrence of 426 authors' keywords (at least five times). Note: extracted by using VOSviewer, Source: authors' own compilation.

section, the interrelations among impactful papers that focus on the implementation of food production within the confines of a circular economy framework are demonstrated through co-citation networks (Fig. 8). This study assumes that the most acceptable way to determine how often various studies regarded a particular area of research is by using a co-citation network. The connections between nodes in the network represent instances where the research papers cite or discuss each other's work. Additionally, the nodes of the clusters represent reference articles addressed by other publications in the concerned database. Collaborative citation networks allow researchers to identify different citation patterns, link academic works, and track the evolution and convergence of specific frameworks.

A small size of purple nodes, green nodes, red nodes, and blue nodes represent the four primary groupings that constitute the co-citation network. The interplay between government regulation and company strategy is central to the Red Cluster's circular economy idea, encompassing important sustainability indicators, obstacles, and possibilities. Articles by Dora et al. (2021), Mak et al. (2020), Teigiserova et al. (2020), Principato et al. (2019), Albizzati et al. (2019), Belaud et al.

(2019), Dahiya et al. (2018), Sagar et al. (2018), Ahamed et al. (2016), Gustavson et al. (2011), and Collinson (2000) are the popular publications within the red cluster. Articles in the green cluster have higher levels of 'betweenness' among themselves and 'page-rank' scores than the other clusters. The degree of variation for proximity among Duan et al. (2020), Farooque et al. (2019), Korhonen et al. (2018), Guillard et al. (2018), Geueke et al. (2018), and Ghisellini et al. (2016) exhibit the strongest affinity within this cluster. On the other hand, blue nodes identify the works of Campos et al. (2022), Ben-Othman et al. (2020), Ishangulyyev et al. (2019), Torres-León et al. (2018), and Kacem et al. (2017), showing a satisfactory or significant level of 'betweenness' and 'page-rank' centrality measures. This result suggests that these nodes play an essential role in influencing the network and are often mentioned in other papers included in the dataset. In a similar vein, the fourth node, i.e., the purple node showing the level of betweenness and page-rank between Donner et al. (2021) and Snyder et al. (2019). These four core nodes include review articles that analyze several conceptualizations of the circular economy as a prospective paradigm for tackling challenges related to production and consumption and ultimately

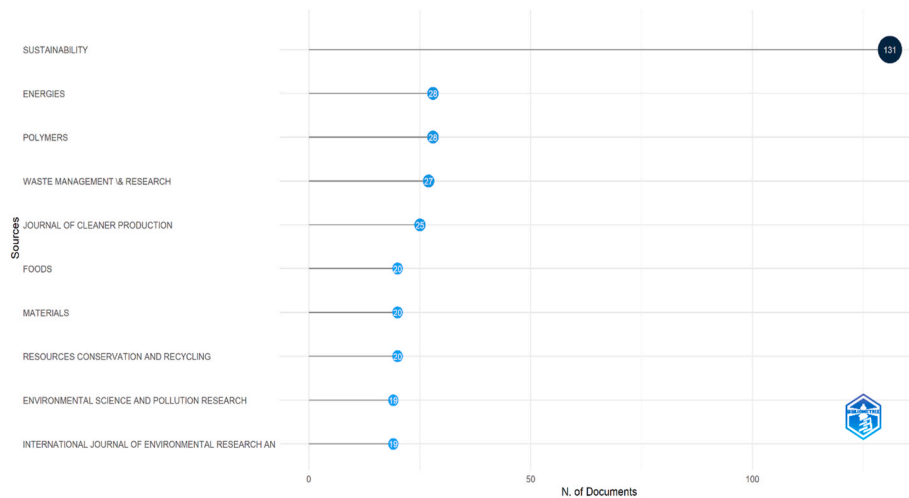


Fig. 6. The most relevant academic journals and publishing sources. Source: authors' own compilation.

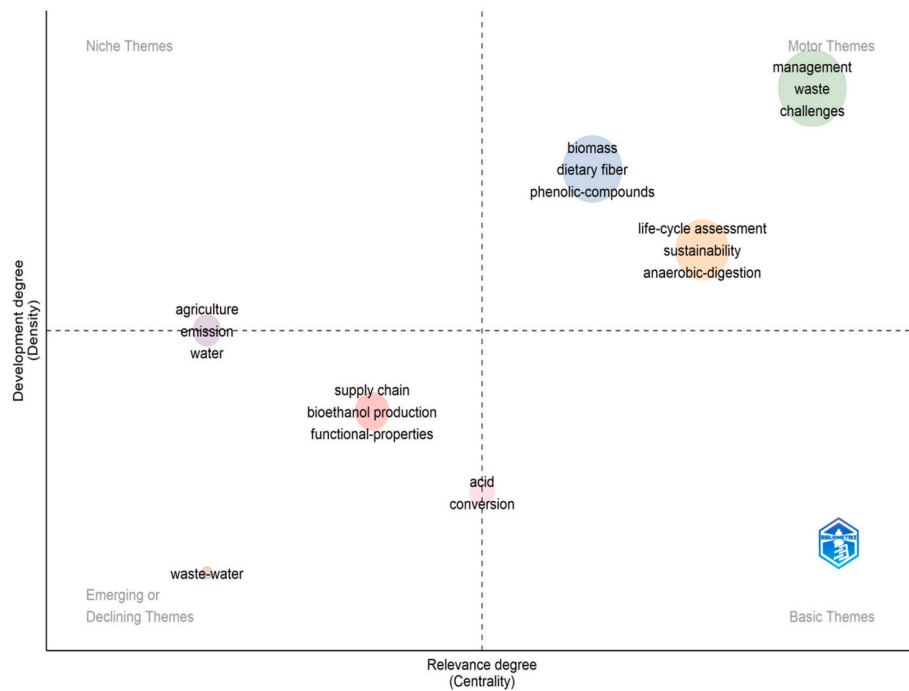


Fig. 7. The thematic map focuses on a specific Circular economy in the Food industry. Source: authors' own compilation.

adherence to natural limitations to substantiate their research arguments and attain a sustainable competitive edge.

3.6. Social structure

The authors of these publications can gain insights into dynamics, group activity, multiculturalism, and relationship outcomes through their collaborative research and studies on social structures. This kind of research collaboration can be beneficial for the researchers to comprehend how these collaborations aid in the creation of novel knowledge. Researchers may examine the dynamics and interactions among academics as they collaborate to produce published papers and how these partnerships contribute to knowledge development by using social structure analysis. Fig. 9 shows the social structure network among writers in this current research domain. However, the present study

investigates and presents the nine clusters of author networks in this analysis part.

The network with the largest number of nodes is most prominently shown by the blue cluster, which includes Hassoun et al. (2022) and Prieto-Sandoval et al. (2022). They are prominent contributors to this cluster, as shown by their prolific publication record and frequent authorship as primary contributors in joint research works. This research cluster is centered on the examination of investigating the impact of sustainability on the industrial sector and the utilization of industry 4.0 technology to accomplish sustainable development goals in the food sectors. Within this cluster, emerges as the core author with the highest number of connections, assuming the role of a mediator among the other authors. The following Fig. 9 of this study shows the collaboration networks demonstrate the collaborative efforts of authors.

The purple cluster include prominent writers such as Parveez et al.

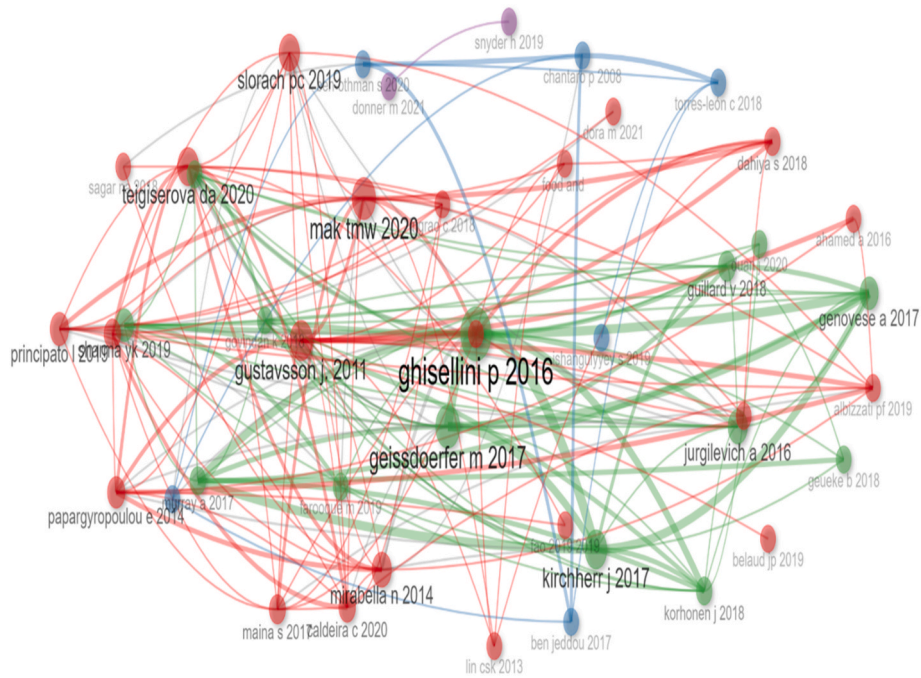


Fig. 8. Co-citation networks exhibit circular economic frameworks, (extracted from biblioshiny) Source: authors' own compilation.

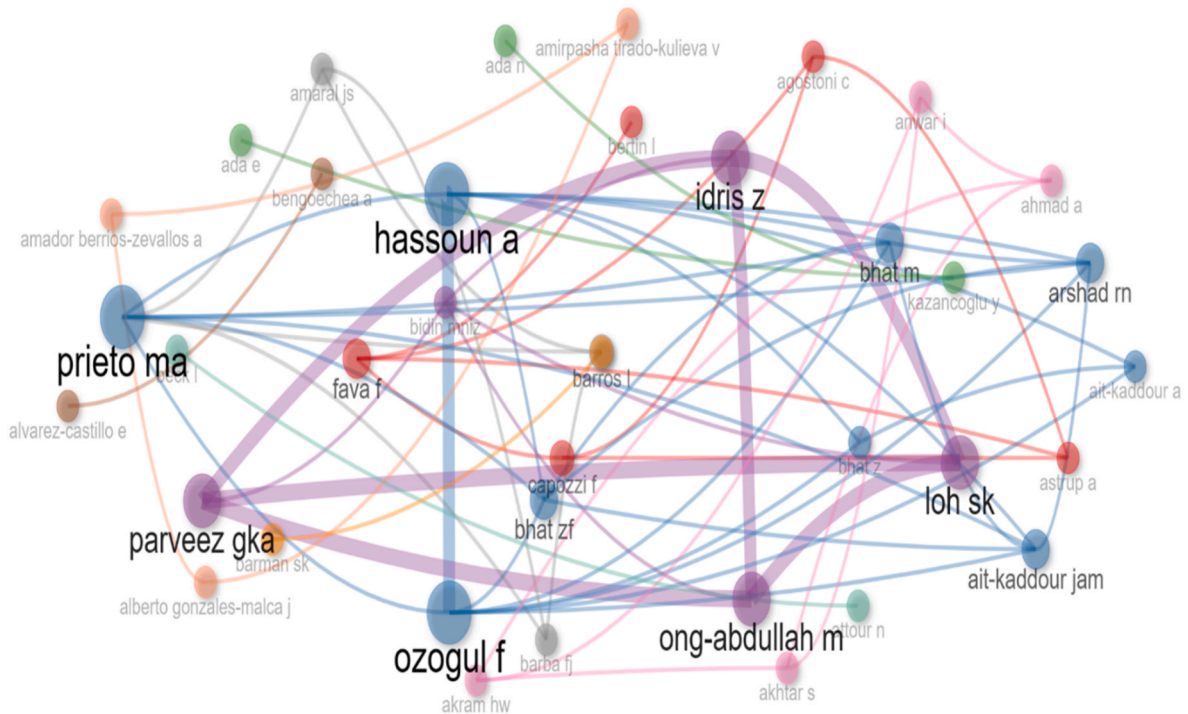


Fig. 9. Collaboration networks highlight the collective efforts of authors working together, (extracted from biblioshiny). Source: authors' own compilation.

(2022) who is associated with academic institutions in Malaysia, seems to have a significant role in connecting the writers. The research conducted by this red cluster places significant emphasis on economic performance and research and development advancements in Malaysia pertaining to palm oil. subsequently, there exists an additional notable group of scholars in red cluster, comprising Agostoni et al. (2023), Capozzi (2022), Fava et al. (2021), Bertin et al. (2019) and who have engaged in collaborative efforts to disseminate research papers about

bioeconomy, Foods Optimized for Sustainable Nutrition, circular economy to reach zero carbon and Consumers' Trust and Perceptions. The pink cluster comprises of the scholars, i.e., Akram et al. (2023) and Ahmad et al. (2020), focusing on the employer branding improves employee attraction and retention and builds a conceptual framework model for perishable food cold-supply-chain management. The green cluster of author cooperation primarily focuses on the in-depth analysis of the factors influencing the transition to more sustainable and circular

food packaging and Industry 4.0 (Ada et al., 2021, 2023). Light red colour cluster explores the eco-friendly methods for treating wastewater at food processing (Zapata-Mendoza et al., 2022). Additional orange clusters explore the theme on recycling food scraps in a sustainable way for developing nations' circular economy (Sarker et al., 2022). The brows cluster presented data showcases the use of proteins derived from biowastes or co-products in the agri-food industry as eco-friendly building blocks within the author collaboration network (Alvarez-Castillo et al., 2021).

However, there was a noticeable uptick in article production during the growth phase. As for the plateau phase, it sustained a steady level of output, contributing to continuous production expansion. Nevertheless, in the period of slowdown, there was a noticeable decline in the quantity of articles generated. In the developmental phase of this analysis, the authors also consider significant global occurrences, such as food waste, valorization, bioactive compounds, the bioeconomy, circular economy, agriculture, bio-products, and drivers of the circular economy. Discussions based on the issue of food scarcity, which need the active engagement of many stakeholders in the adoption of food production sources and the promotion of a circular economy, have been begun since the occurrence of the global energy crisis in 1973 (Winans et al., 2017). Since 2008, there has been an increasing number of publications across many study domains focusing on the concept of the CE (Alcalde-Calonge et al., 2022).

Several prior researchers (for example, (Kumar et al., 2023; Sgroi, 2022; Fogarassy et al., 2020; Szűcs et al., 2017) also examined how companies that have adopted a circular economy strategy were performing; more specifically how well food production is regulated as a strategy for transitioning to a circular economic system. It is widely acknowledged that the circular economy can improve food production systems, rendering them more sustainability in business, and efficient while reducing waste within the context of sustainable food production (Bigdeloo et al., 2021; Prokic et al., 2022). Similarly, the academic work of Mehmood et al. (2021) has explored how a circular economy system reduces access to certain elements needed for food farming systems. In this pertinent, Metson et al. (2020) and Moriarty and Honnery (2014) are the only two examples of the many scholarly works that investigated how to build a sustainable food supply chain for a circular economy adaptation and how to include energy savings in business models within the circular economy framework.

4. Discussion

To evaluate the distribution of circular economy and sustainability in the food business in a bibliometric study using published literature, each article must be meticulously reviewed and categorised. Acknowledging that the publications might be classified under many categories is important. Consequently, most papers were classified under broad categories related to circular economy and sustainability, such as climate change, recycling, waste management, and advanced technology. The following Table 3 represents the top 10 most-cited documents.

From the result of this bibliometric research, the present study reveals that recycling and waste management in the circular economy mainly focus on the food business rather than enhancing food security. This movement emphasizes the need to minimize waste by prioritising recycling, reuse, and regeneration in the development of goods and processes. This may lead to a reduction in food waste, packaging waste, and total resource consumption in the food business. This research is the first attempt to do a bibliometric analysis of the CEs and investigate the advancements, obstacles, and potentialities between 2005 and 2023. The findings of this research demonstrate disparities in the usage of CE in the food business.

Researchers have seen a significant discrepancy in scientific contributions to the development process based on the analysis and findings presented in this work. Furthermore, potential future directions to reduce carbon emissions are a result of sustainable food production and

Table 3

The top 10 most-cited documents in the dataset.

Authors	Journal	Citations	Title
Geissdoerfer et al. (2017)	Journal of Cleaner Production	3865	The Circular Economy – A new sustainability paradigm?
Hopewell et al. (2009)	Philosophical Transactions of the Royal Society B	1380	Plastics recycling: challenges and opportunities
Mirabella et al. (2014)	Journal of Cleaner Production	1228	Current options for the valorization of food manufacturing waste: a review
Gupta et al. (2012)	RSC Advances	1183	Chemical treatment technologies for wastewater recycling—an overview
Guerrero et al. (2013)	Waste Management	1175	Solid waste management challenges for cities in developing countries
Grant and Donaldson (2009)	Nature reviews molecular cell biology	1039	Pathways and mechanisms of endocytic recycling
Giroto et al. (2015)	Waste Management	836	Food waste generation and industrial uses: A review
Cremer et al. (2007)	Current Biology	710	Social Immunity
Ferronato & Torretta (2019)	International Journal of Environmental Research and Public health	675	Waste Mismanagement in Developing Countries: A Review of Global Issues
Martins et al. (2010)	Aquacultural Engineering	533	New developments in recirculating aquaculture systems in Europe: A perspective on environmental sustainability

distribution practices, which include reduced transportation and local sourcing. Circular practices also contribute to the conservation of water resources, soil health, and ecosystems. According to Geissdoerfer et al. (2017), the most cited research is found in CE, which revealed the interconnection between CE and sustainability.

Based on the findings of this study, articles relating to CE on agri-food, waste, and by-products started appearing in 2021, whereas Abbate et al. (2023) found articles relating to more applied and varied CE research on the sustainable food industry starting in 2018. Noteworthy research published since 2018 includes those focused on waste management and sustainability in areas such as wastewater treatment, waste disposal, innovative approaches to sustainable food production, the impact of climate change, and the preservation of ecosystems. These findings indicate a positive development and a consistent pattern in CE studies, suggesting an increased focus on waste management and environmental research. Previous research conducted by Giroto et al. (2015), Ferronato and Torretta (2019), Guerrero et al. (2013), and Cremer et al. (2007) have revealed similar results. Nevertheless, Martins et al. (2010) only examined the publications with the most citations and used the term “environmental sustainability,” while our analysis encompasses a broader range of topics.

Our study reveals a concentration of research activity in the United States, followed by the United Kingdom and China. This geographical pattern suggests a growing worldwide interest in developing sustainable food systems, likely motivated by increasing concerns about food security, resource depletion, and climate change. Consequently, the most common keywords found from prior publications are waste management, recycling, climate change, and food waste - closely align with SDG12 (Responsible Consumption and Production), and SDG13 (Climate Action). SDG 12 aims to halve global food waste and reduce overall waste generation through strategies like recycling and reuse. The emphasis on these keywords resonates with the fundamental principles

of the circular economy, which prioritize minimizing waste and optimizing resource use within the food industry. Moreover, the significant presence of “climate change” as a keyword underscores the circular food economy’s potential contribution to SDG 13. Food waste emits methane, underscoring the need for sustainable practices in the food industry to reduce this emission. By reducing food waste and promoting sustainable practices such as composting, the circular economy can help mitigate climate change.

The thematic map (Fig. 7) resulting from our analysis offers insights into specific research areas within the circular food economy. The first quadrant, focusing on waste management challenges, biomass utilization, life-cycle assessments, and anaerobic digestion, underscores the importance of resource recovery and minimizing environmental impact. This aligns with SDG 12’s objective of fostering sustainable practices throughout the food supply chain. Besides, the second quadrant, highlighting themes related to agriculture, emissions, and water, emphasizes the interconnected nature of these elements within a circular food system. Sustainable agricultural practices that reduce water usage and greenhouse gas emissions are essential for a truly circular food economy, supporting both SDG 12 and SDG 13. Furthermore, the emerging themes in the third quadrant, such as supply chain optimization, bioethanol production, and wastewater treatment, represent promising areas for future research. Enhancing food supply chains to minimize waste, integrating biofuel production into the circular economy, and addressing wastewater treatment are crucial steps toward achieving a closed-loop and sustainable food system. Research in these areas holds significant potential for advancing sustainability goals.

Nevertheless, the main findings drawn from this study are as follows.

1. The United States leads in circular economy research activity, followed by significant contributions from the United Kingdom and China. This geographical pattern highlights a growing global focus on developing sustainable food systems. The increasing interest in this area is likely driven by rising concerns about food security, resource depletion, and climate change. This trend underscores the urgency and prioritization of addressing sustainability challenges in food production and consumption worldwide.
2. Integration of circular economy principles in the food industry reduces waste and enhances resource efficiency by transforming food waste into valuable products like biogas and bio-based materials.
3. Reducing carbon dioxide emissions is one of the environmental advantages that might result from using circular economy solutions in the food industry. It also helps reduce waste and increase resource efficiency, significantly benefiting eco-friendly methods.
4. According to research in the field, the essential elements that drive the circular economy and foster sustainability in the food industry include consumer behavior, policies and economics, financial incentives, and a commitment to social, ecological, and economic concerns.
5. Sustainable waste management practices, including composting and anaerobic digestion, are crucial for minimizing environmental impacts and optimizing resource use.
6. Adopting circular economy practices in the food industry can contribute significantly to responsible consumption and production (SDG-12) patterns and contribute to climate action (SDG-13).

The proposed shift towards a circular economy in the food industry has significant implications for sustainability. Six key recommendations have been formulated to address these implications, aiming to promote sustainable practices throughout the food chain.

1. The integration of circular economy principles into the food industry can significantly reduce waste and increase resource efficiency, which help businesses contribute to global sustainability goals. This approach not only enhances their environmental stewardship but also boosts their sustainability reputation and reduces operational

costs. In addition, this can improve consumer demand for sustainable products and market competitiveness.

2. The findings highlight the importance of sustainable waste management practices. Companies in the food industry can better manage waste generation, collection, and disposal by implementing comprehensive waste management systems. This involves adopting practices such as composting, anaerobic digestion, and biorefining to convert food waste into useful products such as biogas, and bio-based materials. Policymakers can support these efforts by developing regulations and incentives that encourage businesses to adopt sustainable waste management practices.
3. Another critical implication is the need for optimizing food supply chains to enhance sustainability. This includes improving logistics, reducing food loss and waste at each stage of the supply chain, and ensuring efficient resource use. Businesses can implement traceability systems to monitor the flow of products and waste, identify inefficiencies, and make data-driven decisions to optimize operations.
4. The study also underscores the potential of life cycle assessments (LCA) to identify and mitigate environmental impacts throughout the food production and consumption process. By conducting LCAs, companies can pinpoint stages where waste and emissions are highest and implement targeted strategies to reduce their environmental impact. This can lead to more sustainable production practices and help companies meet regulatory standards and consumer expectations.
5. The research highlights the importance of collaboration across the food industry. Stakeholders, including producers, processors, retailers, and consumers, need to work together to develop and implement circular economy practices. This can involve sharing best practices, investing in joint sustainability projects, and creating partnerships to drive innovation in waste management and resource optimization.
6. Encourage regional policymakers to utilize research findings on circular food systems to develop policies that promote sustainable consumption and production patterns (SDG 12) and address climate change (SDG 13). This could involve policies that incentivize food waste reduction, promote resource recovery technologies, and support the adoption of circular economy practices by food industry actors.

Overall, this research reveals key trends in circular economy and sustainable practices in the food industry, highlighting significant benefits alongside challenges such as technological, economic, regulatory, and social barriers. The United States leads in this research, with the United Kingdom and China also making significant contributions. This focus is driven by concerns about food security, resource depletion, and climate change (Santagata et al., 2021; Yang et al., 2023).

Integrating circular economy principles in the food industry can reduce waste and enhance resource efficiency, such as by transforming food waste into biogas and bio-based materials (Li et al., 2024; Ramanauke et al., 2023). One noteworthy example is BioLogiQ, an Idaho-based company transform surplus potato starch into bioplastics. This process significantly reduces plastic pollution. Their NuPlastiQ biopolymers produce stronger and thinner bioplastic films, which reduced plastic usage and fossil fuel consumption by up to 50%. Similarly, Finnish company Rens Original transforms coffee grounds into durable sneakers, addressing waste and environmental impacts in the fashion industry (Kim, 2024). However, this often requires substantial capital and technological adaptation, posing challenges for small to medium-sized enterprises.

Furthermore, the economic feasibility of some technologies, like biogas production remains uncertain. Circular economy practices can reduce carbon emissions and improve eco-friendly methods, but high initial costs and fluctuating market demand for circular products pose significant barriers (Ji et al., 2024; Rossi et al., 2024). However,

inconsistent regulations across regions and insufficient policy incentives hinder adoption (Hartley et al., 2020). Nevertheless, sustainable waste management practices like composting and anaerobic digestion are crucial for minimizing environmental impacts (Gupta et al., 2012). Consumer awareness and cultural attitudes towards waste recycling are also pivotal in adopting circular economy practices (Yang et al., 2023).

Policymakers should provide financial incentives, harmonize regulations, and promote public awareness to support CE practices. Collaboration among stakeholders across the food supply chain and establishing innovation hubs can drive sustainability. In addition, developing performance metrics and continuously updating policies based on feedback are crucial for long-term success.

5. Conclusion

Reducing environmental impact, improving resource efficiency, and increasing profitability are just a few advantages the food sector has seen in adopting circular economy perspectives. Throughout the food value chain, this method promotes collaborative thinking and innovation. Nevertheless, there are specific obstacles that must be overcome to put these concepts into practice. These include shifting consumer sentiment, overcoming legislative obstacles, improving logistics and supply chains, and coming up with creative solutions to the problem of food waste. Despite these obstacles, there are many chances to solve pressing problems like food insecurity and affordability using circular economy concepts. The food sector can greatly enhance sustainability by adhering to these principles, reducing food waste, and encouraging sustainable practices throughout the supply chain. In addition, this method has the potential to open new markets for valuable products made from food scraps.

However, the limited availability and ecological impact of some resources and components used in the generation of the food sector, it is imperative for future research to prioritize the exploration of alternative materials and the adoption of sustainable circular processes. The food industry must integrate the circular economy principles to achieve sustainability development goals and reduce waste. However, challenges like stakeholder collaboration, changing consumer behavior, and the economic viability of circular economy practices may arise.

Despite providing valuable insights, our study has some limitations. The study's bibliometric approach primarily focuses on quantitative metrics such as publication counts and citation frequencies. This emphasis may not fully capture the qualitative aspects and practical impacts of the research. Future research should address these limitations and focus on developing innovative business models and technologies to facilitate the implementation of circular economy principles, expanding to diverse regions for broader insights into global sustainability, and explore the scalability, replicability, and social and environmental impacts of circular economy practices.

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CRedit authorship contribution statement

Mohammad Fazle Rabbi: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Mohammad Bin Amin:** Writing – original draft, Validation, Supervision, Resources, Project administration, Investigation, Funding acquisition, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal conflicts that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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