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Research Update on Food Waste Composting: A Bibliometric Analysis and Way Forward

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Composting is a biological process that converts organic waste into compost, an organic fertiliser. As a waste management technology, the use of composting in managing food waste is gaining more attention these days. In recent years, many studies have been done to analyse the research trend in solid waste management using bibliometric analysis, which showed the potential to analyse food waste composting trends using this tool. Bibliometric analysis is used in this study to map and visualise the food waste composting research trend indexed in the SCOPUS database between 1987 and 2021. One thousand seven research papers were exported from the SCOPUS database during the study period, VOSviewer and Microsoft Excel were used to analyse the exported data. The results show that there were 1,007 publications with 31,335 citations. An increasing trend in publication numbers was observed, especially in the recent 15 y. China, US and India are the top 3 contributed countries in this research subject over the 34 y research period, with the US being the top contributed country before 2000. In recent years, China has become the major contributor to food waste composting research. Keywords analysis was done using VOSviewer, and “soil” was found to be strongly linked to the food waste composting research, followed by “emission” and “organic matter”. The appearance of strongly linked keywords such as “emission” and “landfill” reveals the potential environmental issues that are the major criteria to be of concern when working on food waste composting. The presence of keywords such as “soil”, “plant”, “application”, and “organic matter” indicates the potential of compost usage as soil amendments. An upward trend in the publication numbers is likely to continue in the next decade. Further study on environmental issues and compost quality might contribute to the safety and efficient use of compost in a soil application.

1. Introduction

Municipal solid waste (MSW) generation is increasing with rapid urbanisation and population growth (Xu et al., 2021). According to World Bank (2022), the world was estimated to generate 2.24×10^9 t of MSW, equal to an average of 0.79 kg of waste per person per day. It is expected to increase by 73 % from 2020 to reach 3.88×10^9 t by 2025 (World Bank, 2022). The sharp increment of MSW generation is predicted to affect developing countries mostly due to immature practices in waste management (Isibika et al., 2019). It is crucial to maximise the bioavailability of MSW as it is considered a source of pollution and a major biomass resource (Hameed et al., 2021).

As a biological treatment, composting is considered a more economical and safer treatment with high utilisation value for decomposing and recycling biomass resources, especially in developing countries (Chen et al., 2021). Composting has also been shown to reduce residual antibiotics (Zhang et al., 2018) and heavy metals availability (Lim et al., 2018), thus enabling the safe use of materials. Mature compost without pathogen detection can be a potential substitution for chemical fertiliser to improve soil quality and crop productivity, maintaining soil fertility by reducing nutrient loss, suppressing soil-borne diseases and reducing water pollution (Lim et al., 2021).

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The research on composting started in the 1930s and gradually increased until the 1990s, which has an exponential growth until now. While the first well-recorded food waste composting article was recorded in 1987, by Natour, about the challenges of using municipal and household refuse as composting material for crop production and soil conservation in Kuwait (Natour, 1987). Similar to the composting research, the number of food waste composting research has gradually increased yearly and gained more attention in recent 10 – 15 y. The research scopes are complex due to the heterogeneity of the composting methods and inputs used. It is essential to systematically study food waste composting research to understand the current global status and research trends.

Bibliometric is defined as the use of statistical methods to analyse the bibliometric publications data and has been widely used to present the relations of research domains using quantitative methods (Kulakli, 2021). It is a useful method for identifying the research trends and coming issues and evaluating the research performance of institutions, journals and researchers based on historic publication information (Li et al., 2018). The publications on food waste composting research have been increasing in recent years; however, the research trends and development directions have rarely been reviewed.

This study presents a bibliometric analysis to elucidate the research progress and trends in food waste composting. The search was conducted in the time range from 1987 – 2021 to identify the global research trends. Then the time range is narrowed down into four different time frames (1987 – 2001, 2002 – 2011, 2012 – 2016 and 2017 – 2021), targeting to summarise the research development, technological advancement and current development trends for the food waste composting process. Unlike the previous review, which focused on a certain concept or field of interest, this study focused on a broad analysis of food waste composting and targeted to identify the missing gaps that need to be studied.

2. Methods

The SCOPUS database (www.scopus.com) was selected as the database source for bibliometric analysis. Keyword “compost*” was searched under the categories of title, abstract and keywords, in combination with the keyword “kitchen$waste$” OR “food$waste$” under the category of abstract. Figure 1 shows the details of the publication selection under the SCOPUS database and the analysis performed, with the search string presented at the top left of the figure. Excel 2019 was used to analyse the total publication and citation counts, developing trends over countries, while VOSViewer was used for the keywords co-occurrence and research trend analysis.

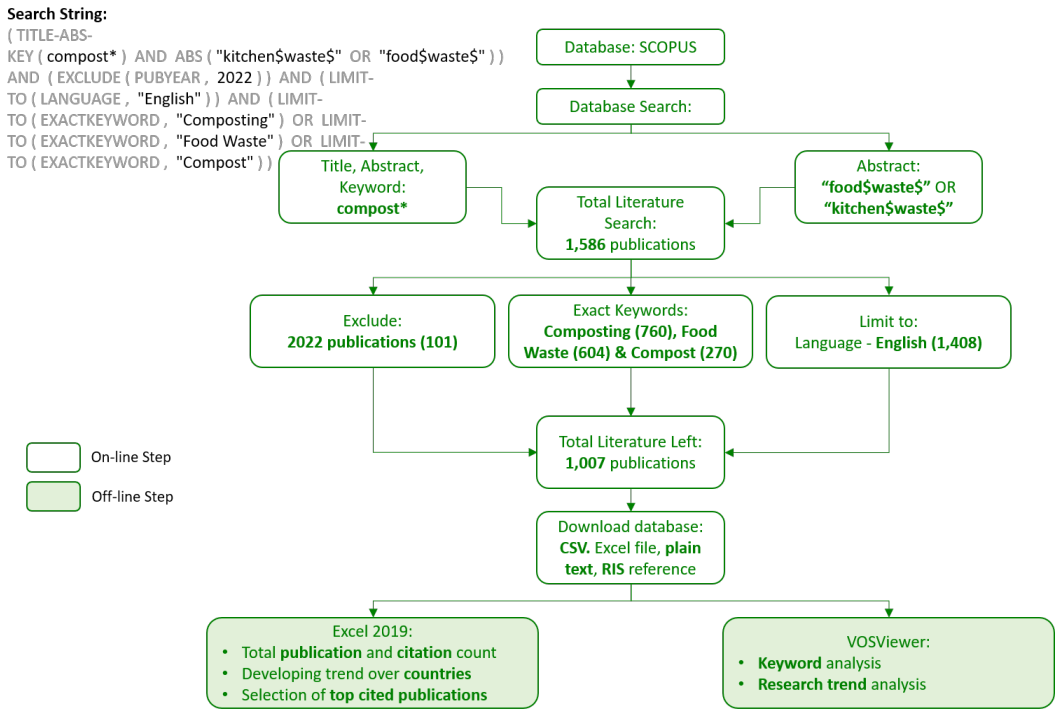


Figure 1: Detailed bibliometric analytical process flow for “food waste composting” under the SCOPUS database

3. Results and discussions

The bibliometric analysis of food waste composting is presented in this section. Figure 2 indicates the number of publication evolution over the years, Figure 3 shows the top productive countries/territories, and Figure 4 indicates the research trends through keywords co-occurrence analysis under four different time frames: (a) 1987 – 2001, (b) 2002 – 2011, (c) 2012 – 2016 and (d) 2017 – 2021.

The first analysis was conducted to observe the total number of documents published on food waste composting. The first document on food waste composting was in 1987. In total, 1,007 documents have been obtained following the screening from 1987-2021. The total number of publications in the first 15 y was below 50. Since 2005, the exponential growth of document numbers has been observed (Figure 2(b)). This outcome is correlated with the annual increase in food waste production and the urge to develop a sustainable food waste management strategy to overcome the issue. According to UNEP (2021), about 931 Mt of food waste was generated in 2019, with 61 % from households, 26 % from food service and 13 % from retail. The global food waste generation is expected to grow 70 % by 2050 (UNEP, 2021).

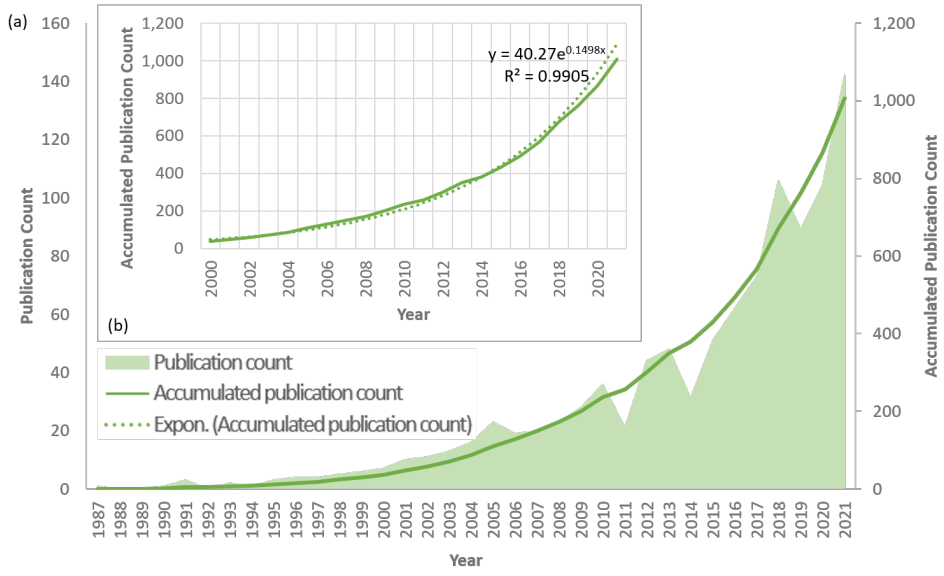


Figure 2: (a) The annual and a cumulative number of publications in 1987 – 2021, (b) the exponential trendline of publications number in 2000 – 2021.

Figure 3 shows the contribution of the top productive countries/territories in food waste composting. China and the USA have similar document numbers in the research area. Comparing the research progress, China surpassed the USA in 2013 with the fastest growth rate from 2013 to 2021. India and Malaysia have also achieved a faster growth rate since 2015. The reason for these phenomena was that developed countries started with a relatively better management system much earlier in the research area. Thus, a more stable research trend was observed in developed countries. For China and other developing countries experiencing rapid industrialisation and urbanisation, MSW production has become a major challenge. According to Li et al. (2018), China has become the largest MSW generator since 2004, and USD 2.1 x 10^{11} was invested in solid waste disposal projects from 2006 - 2010. In 2000, China was recorded to dispose of 118.2 Mt of garbage. A sharp increment (32 %) in garbage disposal was observed until 2005, followed by a 1 – 7 % yearly increment, reaching 242.06 Mt garbage disposal in 2019 (Statista, 2022). Similar to Malaysia, rapid food waste production in Malaysia also experienced dramatic growth over these years. Food waste production in Malaysia was also observed to increase from 465 $t \cdot d^{-1}$ to 15 $kt \cdot d^{-1}$ from 2009 to 2013 and further increased to 17,007 $t \cdot d^{-1}$ in 2021 (Yuen, 2022). A dropping trend was observed in the years 2019 and 2020 for most countries, which can be greatly related to the COVID-19 pandemic. According to Pappalaardo et al. (2020), during the pandemic lockdown, food waste decreased even though there was an increased amount of food purchases. Burlea-Schiopoiu et al., (2021) also observed more people exhibiting food waste reduction behaviour after the pandemic. Besides, the pandemic lockdown also affected the research progress. The research project might be suspended due to the movement control or insufficient food waste to run the composting research. The drift of research interest toward COVID-19-related topics might be another reason for the dropping trends observed.

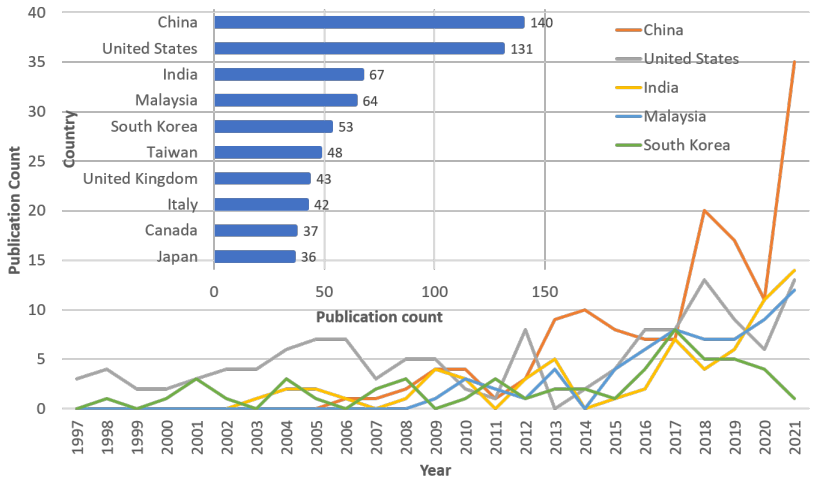


Figure 3: Top 10 productive countries/territories and the top 5 productive countries/territories' development trends in food waste composting

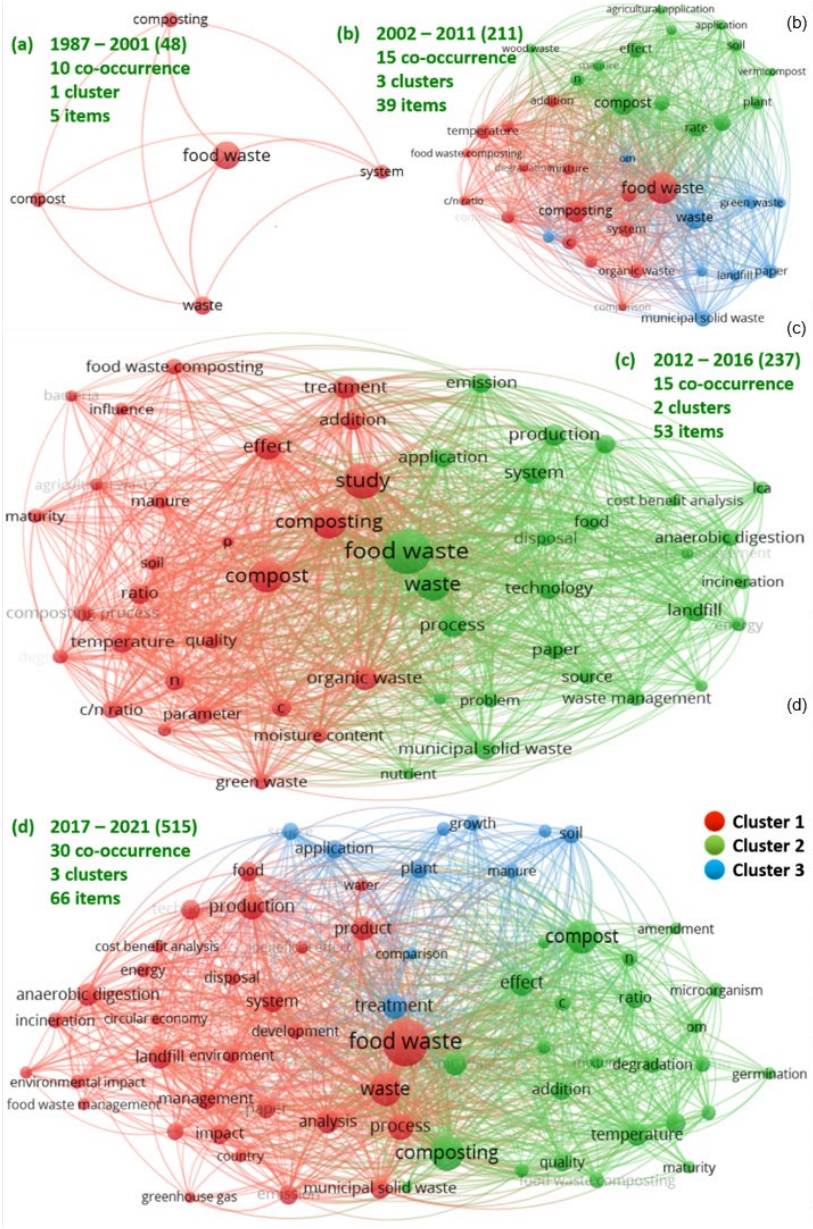
The keywords co-occurrence analysis was done using VOSViewer under four different time frames with the significant research trends under different time frames and the corresponding publication numbers bracketed in Figure 4. The research on food waste composting has a relatively slow development in the first time frame (1987 – 2001). Only 48 articles were observed that focused more on the potential of using composting in solving the problems due to increased food waste production. From 2002 – 2011 where significant food waste generation was observed, more focus was put on developing a better system and the potential use of the mature compost. As food waste is high in N contents and low in bulk density, green and wood wastes with high C content and bulk density were introduced as co-composting materials to improve the process succession rate.

From 2012 – 2016, more mature technology was developed with detailed analyses, such as elemental analysis and maturity and stability test, the research aimed to understand further the composting process. Comparisons of waste management technologies became a major trend by comparing the potential rewards and costs and process emissions between technologies to ease the selection. From 2017 – 2021, the research trend involved a combination of previous research. Cluster 1 (Red) indicates the issues related to food waste, the related management strategies, and their respective environmental impacts and cost benefits. Cluster 2 (Green) indicates the composting process and the analyses, and the respective amendments made to improve the process. Cluster 3 (Blue) is mainly on compost application and the comparison of the relative effects, such as plant growth and soil quality improvement, with other organic materials inputs.

When looking at the top 10 cited articles under food waste composting in recent 5 y, inoculation of composting piles with either black soldier fly or bacterial inoculant accounted for 64 % of the total citation. Especially for the inoculation with black soldier flies, it has become a very hot topic in recent years, with the increasing argument on the roles of composting in waste management under the development of other treatment approaches, particularly anaerobic digestion, which enables cascade utilisation where extraction (waste to chemical) or conversion could be done before and after. The digestate could be utilised for other purposes or returned later to the soil, and the GHG savings potential is higher than composting. The inoculation of black soldier fly larvae can shed light on food waste composting research. During the process, the food waste is converted not only to compost but also to dry larvae, which can be used as animal feed. Black soldier fly larvae are found to be versatile in their feedstock preferences and can be used to treat a variety of organic waste streams, provided that the total volatile solids and nitrogen content are sufficiently high to support larval development (Lalander et al., 2019). Although the life cycle assessment on this does not seem to give a very promising outcome due to the drying process that requires high energy input, the replacement of the chemical fertiliser with compost and the replacement of animal feed or diesel production feedstock with dried larvae might give some improvement on it. As it is a quite new topic in this research area, more research is needed to investigate the pros and cons of the inoculation of black soldier fly larvae in terms of life cycle assessment and process improvement.

The abovementioned research shows that an exponential upward trend in food waste composting research will likely continue in the next few decades. The following topics are predicated as the hot issues in the near future: (i) The environmental impact and cost benefits of food waste composting and the potential of achieving a circular economy between food waste, compost product and soil system; (ii) the improvement of the final food waste compost quality for the safety and efficient used as a soil fertiliser; (iii) the potential of food waste composting to

achieve cascade utilisation. The future hot topics and issues were predicted by looking into the food waste composting research development and comparing them with the developing trend of those well-developed technologies (especially AD, as a biological treatment that shares the same feedstocks, it is essential to figure out the benefits of composting over AD). The future trends are also predicted by looking at the development of the recent hot topic related to the composting field (e.g. circular economy). The last but not least, the unfilled gaps in composting research (e.g. the potential improvement in compost application).



(b)

Major keywords	Total link strength
Food waste	1143
Compost	703
Waste	668
Composting	661
Rate	430
Municipal solid waste	372
Treatment	366
Temperature	328
N	327
Organic waste	323

(c)

Major keywords	Total link strength
Food waste	1792
Composting	1023
Effect	1021
Organic waste	703
Process	622
Treatment	606
System	536
Technology	437
Application	361
Anaerobic digestion	336

(d)

Cluster 1 keywords	Total link strength
Food waste	4321
Waste	2260
Process	1656
Landfill	1278
Anaerobic digestion	1118

Cluster 2 keywords	Total link strength
Composting	2754
Waste	2260
Composting process	1046
Quality	849
N	777

Cluster 3 keywords	Total link strength
Plant	864
Soil	829
Application	803
Growth	603
Manure	545

Figure 4: Clustering of the keywords co-occurrence analysis over the plain text of 1,007 publications. Tables at right listing the total link strength of the major keywords for different time frame analysis.

4. Conclusions

In conclusion, food waste composting is still under its exponential growth with the rapid increment of food waste production yearly. An advancement of mature technology for food waste composting has been developed over 40 y of research. Recent research trends have focused on the environmental impact and cost-benefit of the process and the potential of the compost product being used as a soil fertiliser. The safety and precision application of food waste compost to promote plant growth and soil fertility will continue to be a hot research topic in the next few decades. A comprehensive comparison between composting and other alternatives from

different perspectives (economically, environmentally, socially) and scale based on different circumstances have to be assessed and optimised.

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