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Biodegradable Food Packaging with The Addition of ZnO Nanoparticles: A Bibliometric Analysis with Computational Mapping using VOSviewer

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ABSTRACT

Zinc oxide nanoparticle properties that can improve the quality of biodegradable food packaging become the impetus to develop research on biodegradable food packaging with the addition of ZnO nanoparticles. However, it is not yet known whether research on this topic is still widely carried out or not. This study aims to know the development of this research topic from 2013 to 2022 through a bibliometric approach with computational mapping analysis using VOSviewer. The search for article data from Google Scholar database was carried out by entering a query language into Publish or Perish. There are 207 articles that meet the criteria after being filtered by reading the title and abstract. Based on the number of publications each year, research on this topic is relatively increasing. Based on three mapping visualizations from VOSviewer results, the relation of packaging to properties or capabilities, such as biodegradability, extending the food shelf life, and antimicrobial activity is still rarely discussed. These results can be a reference for researchers to develop research on biodegradable food packaging with the addition of ZnO nanoparticles, with a discussion focusing on these properties or capabilities.

Introduction

Packaging is one way to preserve food's properties, functions, and characteristics because it protects food from environmental factors such as oxygen, dust, light, moisture, microbes, and mechanical stress. Synthetic polymer-based materials dominate most food packaging; this polymer has good mechanical and barrier properties but takes centuries to decompose, so it significantly contributes to solid waste [1]. So, in this case, biodegradable packaging—packaging based on natural biopolymers that can be biodegraded—becomes one of the solutions to preserve products and extend their shelf life. This natural biopolymer-based packaging is readily biodegradable but has poor mechanical and barrier properties that limit its application in food packaging. Mixing with synthetic polymers, composites of different biopolymers, as well as the addition of various fillers or nanofillers are some of the approaches that can be taken to improve the properties of biopolymer films [2] [3].

One commonly used nanofillers is zinc oxide nanoparticles (ZnO NPs). ZnO NPs can be used as fillers in biodegradable film packaging due to their antimicrobial properties against Gram-positive and Gram-negative bacteria [4]. In addition to antimicrobial properties, adding ZnO NPs can improve physical properties such as mechanical properties and water vapor barrier in packaging films [5] [6] [7]. Moreover, ZnO NPs are recognized as safe by the United States Food and Drug Analysis (US FDA), so they can be used in the food sector [8] [9] [10] [11]. Based on their effect on the environment, ZnO NPs are known as environmentally friendly nanofiller. Regarding its availability, they are low cost and easy to obtain [12].

Its properties that can improve the quality of food packaging, ease of access, and safety for food and the environment are the impetus to

continue to develop research on biodegradable food packaging with the addition of ZnO nanoparticles. However, it is not yet known whether research on this topic is still widely carried out or not.

The development of research on biodegradable food packaging with the addition of ZnO nanoparticles can be known using an analytical technique, namely bibliometric analysis. Bibliometric analysis is a method of collecting much information related to citations through data mining and examining it quantitatively through statistics and mathematics [13]. This technique also allows researchers to visualize data through graphs, clusters, and networks that can be used to review global scientific outputs of specific research interests [14].

Bibliometric analysis has been carried out on various research topics, including food packaging materials [15], sustainable and healthy packaging [16], edible coatings [17], food preservation [18], also harvest and postharvest technology to preserve food [19].

Although bibliometric analysis has been widely carried out, there has been no research on the bibliometric analysis of biodegradable food packaging with the addition of ZnO nanoparticles. Therefore, in this study, a bibliometric analysis of the articles indexed by Google Scholar will be done through computational mapping using VOSviewer software. This study aims to know the development of this research topic in the last ten years, from 2013 to 2022. The results of this study are expected to be a reference for researchers in deciding the research theme to be taken along with the discussion in it, especially those related to biodegradable food packaging with the addition of ZnO nanoparticles.

Methods

Methodology of Collecting Data

In this study, article data was collected from the Google Scholar database. The criteria for the selected articles were articles published from 2013 to 2022 that discussed food packaging (including coatings) based on biodegradable polymers with ZnO nanoparticles added. To get this, Publish or Perish reference manager application was used. The search for article data was carried out by entering a query language into the Publish or Perish software using the title words "packaging OR coating OR shelf life AND zinc oxide OR ZnO" and the keywords "food packaging AND biodegradable OR biodegradability AND ZnO nanoparticles". The publication name is filled with "journal OR food OR packaging OR coatings OR polymers OR science OR nanomaterials" so that only articles from journals containing that word will appear. The article data obtained were filtered based on criteria through reading titles and abstracts. Then the collected article data that meet the criteria are exported into two types of files: comma separated value (*.csv) for processing article bibliometric data using Microsoft Excel software and research information systems (.ris) for computational mapping of article bibliometric data using VOSviewer software.

Methodology of Obtaining Map

Article data in the CSV file type from Publish or Perish is analyzed using the VOSviewer application to visualize the bibliometric network and evaluate trends in article data through mapping. The mapping formed has three variations: network visualization, density visualization, and overlay visualization. All mapping is based on the network or the connection between existing terms. When creating a bibliometric map, terms are set to be found with a minimum of 3 occurrences. Total terms that met the threshold were filtered to remove less relevant words.

Results and Discussion

Results of Article Data Search

Searching Google Scholar-indexed article data using a query language in the Publish or Perish reference manager application yielded 244 articles. Articles that did not meet the criteria after being filtered by reading the title and abstract were removed, so there were only 207 data articles. There are several examples of article data obtained from search and filtering results. The 20 articles with the highest number of citations are shown in Table 1.

Table 1. Article data of biodegradable food packaging with the addition of ZnO nanoparticles

No.	Authors	Title	Year	Cites	Ref.
1	Yadav et al.	Chitosan based ZnO nanoparticles loaded gallic-acid films for active food packaging	2021	97	[20]
2	Roy et al.	Carboxymethyl cellulose-based antioxidant and antimicrobial active packaging film incorporated with curcumin and zinc oxide	2020	158	[9]
3	Arroyo et al.	Antimicrobial active edible coating of alginate and chitosan add ZnO nanoparticles applied in guavas (Psidium guajava L.)	2020	104	[21]
4	Sun et al.	Multifunctional bionanocomposite films based on konjac glucomannan/chitosan with nano-ZnO and mulberry anthocyanin extract for active food packaging	2020	86	[22]
5	Jayakumar et al.	Starch-PVA composite films with zinc-oxide nanoparticles and phytochemicals as intelligent pH sensing wraps for food packaging application	2019	149	[23]
6	Indumathi et al.	Mahua oil-based polyurethane/chitosan/nano ZnO composite films for biodegradable food packaging applications	2019	116	[24]
7	Indumathi et al.	Antimicrobial and biodegradable chitosan/cellulose acetate phthalate/ZnO nano composite films with optimal oxygen permeability and hydrophobicity for extending the shelf life of black grapefruits	2019	91	[25]
8	Amjadi et al.	Application of Reinforced ZnO Nanoparticle-Incorporated Gelatin Bionanocomposite Film with Chitosan Nanofiber for Packaging of Chicken Fillet and Cheese as Food Models	2019	90	[26]
9	Ejaz et al.	Zinc oxide nanorods/clove essential oil incorporated Type B gelatin composite films and its applicability for shrimp packaging	2018	107	[27]
10	Babaei-Ghazvini et al.	Preparation of UV-protective starch/kefiran/ZnO nanocomposite as a packaging film: Characterization	2018	83	[28]
11	Noshirvani et al.	Novel active packaging based on carboxymethyl cellulose-chitosan-ZnO NPs nanocomposite for increasing the shelf life of bread	2017	155	[29]
12	Castro-Mayorga et al.	The impact of zinc oxide particle morphology as an antimicrobial and when incorporated in Poly(3-hydroxybutyrate-co-3-hydroxyvalerate) films for food packaging and food contact surfaces applications	2017	96	[19]

Table 1. (continued)

No.	Authors	Title	Year	Cites	Ref.
13	Rahman et al.	Flexible chitosan-nano ZnO antimicrobial pouches as a new material for extending the shelf life of raw meat	2017	87	[30]
14	Naamani et al.	Chitosan-zinc oxide nanoparticle composite coating for active food packaging applications	2016	246	[12]
15	Marra et al.	Polylactic acid/zinc oxide biocomposite films for food packaging application	2016	221	[31]
16	Salarbashi et al.	Development of new active packaging film made from a soluble soybean polysaccharide incorporating ZnO nanoparticles	2016	75	[32]
17	Sanuja et al.	Synthesis and characterization of zinc oxide–neem oil–chitosan bionanocomposite for food packaging application	2015	160	[33]
18	Kamal et al.	Adsorption and photocatalyst assisted dye removal and bactericidal performance of ZnO/chitosan coating layer	2015	138	[34]
19	Arfat et al.	Shelf-life extension of refrigerated sea bass slices wrapped with fish protein isolate/fish skin gelatin-ZnO nanocomposite film incorporated with basil leaf essential oil	2015	124	[7]
20	De Silva et al.	ZnO deposited/encapsulated halloysite–poly(lactic acid) (PLA) nanocomposites for high performance packaging films with improved mechanical and antimicrobial properties	2015	119	[35]

Development of Research

Article data about biodegradable food packaging with the addition of ZnO nanoparticles are grouped by year of publications, so the number of publications for each year in the last decade is obtained. The data shows that research on this topic is relatively increasing every year, as seen in Figure 1. From 2013 to 2015, the number of publications doubled from each previous number. There was only a slight decrease in 2016 to become 11 publications. After that, the increase occurred gradually from 2016 to 2019 and finally experienced a significant boost when entering 2020. A less considerable difference but still increasing occurred in 2021. The data in 2022—which was obtained in September 2022—shows the potential increasing number of publications as well because there have been 34 data publications when the data has not been fully obtained until the end of the year.

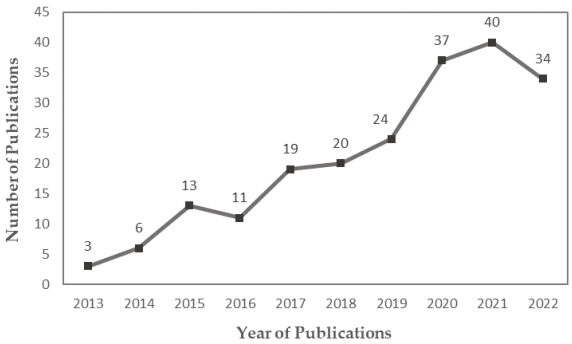

Figure 1. Level of development in biodegradable food packaging with the addition of ZnO nanoparticles

From these results, it can be said that the popularity of research about biodegradable food packaging with the addition of ZnO nanoparticles is increasing and has become a research interest lately.

Mapping Visualization using VOSviewer

Computational mapping of article data using VOSviewer provides 88 terms that meet the threshold. The results of filtering and removing less relevant words produce 56 terms often related to biodegradable food packaging with the addition of ZnO nanoparticles. In this study, each term was analyzed using three mapping forms: network visualization, overlay visualization, and density visualization.

In network visualization, each term is connected to other terms by depicting an interconnected network, as shown in Figure 2. Each term is included with circles of various colors and sizes. The circle size of each term depends on the frequency of the term appearing. The more often it seems, the larger the circle size[36] . Terms with the same circle color indicate that they are a group. The group of terms included in the map is called a cluster. This cluster shows a fairly close relationship between one term and another. There are 5 clusters generated from the data mapping of this research. Cluster 1, 2, 3, 4, and 5 are marked in red, green, blue, yellow, and purple, respectively.

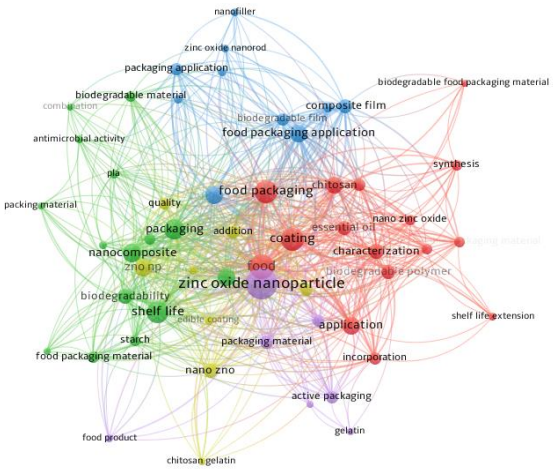

Figure 2. Network visualization on the topic of biodegradable food packaging with the addition of ZnO nanoparticles

From the clusters and terms that appear in the network visualization, it can be seen that research on biodegradable food packaging with the addition of ZnO nanoparticles has three key terms, namely food packaging, which is included in cluster 1 with 43 links and a total link strength of 109 (see Figure 3). The second term is zinc oxide nanoparticle which belongs to cluster 5 with 51 links and a total link strength of 225 (see Figure 4). The third term is biodegradability which belongs to cluster 2 with 28 links and a total link strength of 55 (see Figure 5).

The link shows the number of links the item has with other items, while total link strength shows the total strength of the item's links with other items [42]. So that means the term food packaging has 43 links with other terms such as zinc oxide nanoparticles, biodegradability, biodegradable material, coatings, antimicrobial activity, and other terms that can be seen in Figure 3, in which the total link strength of the 43 links is 109.

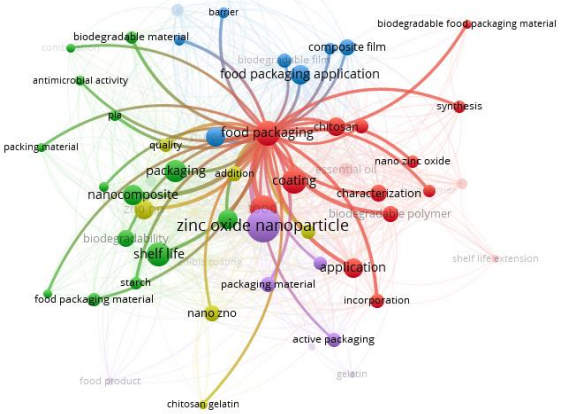

Figure 3. Network visualization of food packaging term

The term zinc oxide nanoparticle also links food packaging, biodegradability, and antimicrobial activity. Of the 49 remaining links that can be seen in Figure 4, the differences are seen in their links with terms such as nanofiller and shelf life extension. This network indicates that zinc oxide nanoparticles are discussed as nanofiller that can extend the shelf life of food when used as food packaging due to their antimicrobial activity. However, the small circle size on these terms indicates that discussions in that direction are still rarely carried out.

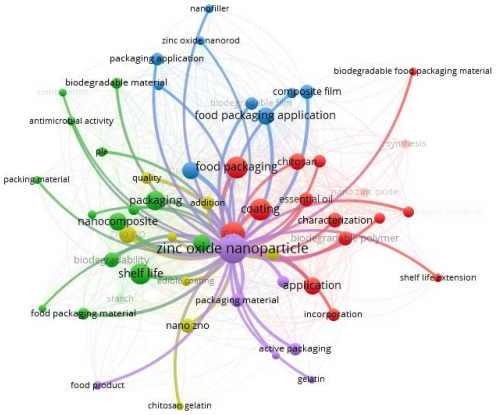

Figure 4. Network visualization of zinc oxide nanoparticle term

Food packaging and zinc oxide nanoparticles term are also inseparable from biodegradability term. The total link strength with 26 other links which can be seen in Figure 5 is 55. So, it can be said that biodegradability has a relatively low link strength compared to zinc oxide nanoparticles and food packaging. The relatively low link strength indicates that biodegradability is still rarely discussed because total link strength indicates the number of publications where two linked terms appear together [42].

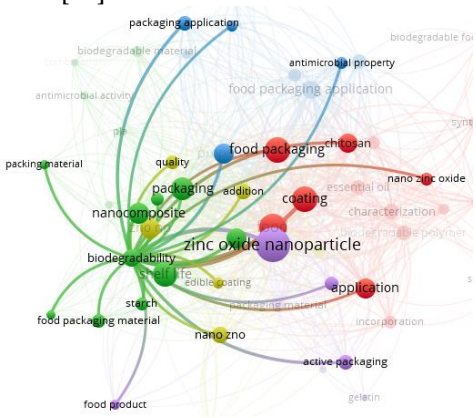

Figure 5. Network visualization of biodegradability term

In the overlay visualization shown in Figure 6, each term has a different color circle depending on what year the term is mostly found in the range of 2018 – 2021. Biodegradability have been widely discussed around 2019. The terms discussed recently (2021) are antimicrobial activity and shelf life extension. The mapping illustrates that research on biodegradable food packaging with the addition of ZnO nanoparticles has been studied recently and is still developing, especially in terms of antimicrobial activity and its ability to extend the shelf life of food.

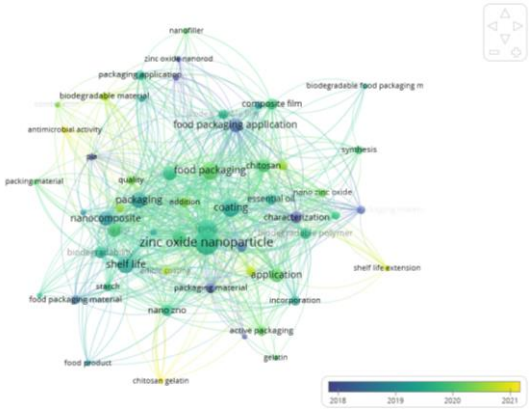

Figure 6. Overlay visualization on the topic of biodegradable food packaging with the addition of ZnO nanoparticles

In density visualization, the wider the area behind the term and the brighter the yellow color, indicating that the term appears more often and vice versa [42]. So based on Figure 7, it can be seen that the discussion related to the term zinc oxide nanoparticle, food packaging, and coating has a high number of studies, while the term biodegradability, shelf life extension, and antimicrobial activity is not. This visualization shows that research on this topic still rarely discusses the ability of packaging to decompose, the ability of packaging to extend the food shelf life, or the antimicrobial activity of the packaging itself.

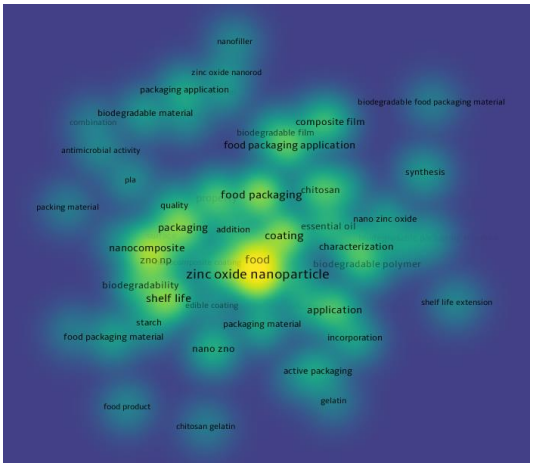

Figure 7. Density visualization on the topic of biodegradable food packaging with the addition of ZnO nanoparticles

Based on three visualizations of the

collected article data, the terms food packaging (including coating) and zinc oxide nanoparticles are the main discussions that are often mentioned in recent research. However, its relation to properties or capabilities, such as biodegradability, shelf life extension, and antimicrobial activity, is still rarely discussed. Biodegradability was discussed more in 2019. Meanwhile, shelf life extension and antimicrobial activity were frequently mentioned in 2021. So, in this case, researchers can develop research on biodegradable food packaging with the addition of ZnO nanoparticles, with the discussion that focuses both on things that were more discussed in previous years, such as biodegradability, as well as issues that were recently discussed such as shelf life extension and antimicrobial activity.

Conclusion

This bibliometric analysis analyzed the development of research on biodegradable food packaging with the addition of ZnO nanoparticles in the last decade, from 2013 to 2022, with computational mapping using VOSviewer. In this paper, 207 articles that meet the criteria give the results that show research on this topic is relatively increasing even though there is a slight decrease in 2016, also in 2022 that the data has not been wholly obtained until the end of the year. Network visualization, density visualization, and overlay visualization from VOSviewer show the relation of packaging to properties or capabilities, such as biodegradability, extending the food shelf life, and antimicrobial activity are still rarely discussed. This work can provide a perspective for future research in this studied field to develop research focusing on these properties or capabilities, moreover this research is still quite popular in being developed.

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