POSSIBILITIES AND LIMITATIONS OF BIODEGRADABLE PLASTICS

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ABSTRACT

This study examined societal interest in biodegradable plastics as portrayed in South Korean media, analyzing trends, topics, and related keywords to understand public perceptions and discourse. Big data analysis was conducted on news articles from 104 major South Korean media outlets between 2014 and 2023 using the BIGKinds platform. The frequency of articles mentioning biodegradable plastics and related keywords were analyzed. A total of 4,403 articles were identified, with a peak in coverage in 2021 followed by a slight decline. Keyword analysis revealed a focus on "eco-friendly" materials like PHA and PLA, and concepts like recycling and commercialization. Media attention toward biodegradable plastics significantly increased, reflecting growing public awareness of sustainable alternatives to conventional plastics. However, challenges such as degradation conditions, waste management integration, and economic feasibility require further attention.

KEYWORDS

Biodegradable Plastics; BIGKinds Platform; BIGKinds ; South Korea; Sustainability

1. INTRODUCTION

In contemporary society, plastics, particularly those of the non-biodegradable variety, have become indispensable materials across a myriad of applications, from packaging to construction, and beyond [1] However, the environmental ramifications of these materials, characterized by their persistent nature and resistance to degradation, have precipitated mounting concerns regarding sustainability and ecological well-being [2]. The accumulation of plastic waste in landfills and natural habitats, coupled with its consequential pollution in marine environments, underscores an urgent need for viable alternatives that can mitigate such environmental impacts [3]. In this context, biodegradable plastics emerge as a promising solution, heralded for their capacity to decompose into water and carbon dioxide through microbial action under natural conditions [4]. This decomposition process, facilitated by bacteria, fungi, and algae, presents a stark contrast to the long lifespan of conventional plastics in the environment [5]. Furthermore, the versatility in the production of biodegradable plastics, derived from a diverse array of raw materials including both biomass and fossil fuel-based compounds, adds to their appeal as a sustainable alternative [6]. The environmental benefits of biodegradable plastics extend to their end-of-life, where they can be composted under appropriate conditions, thereby reintegrating into the ecological cycle without leaving harmful residues [7]. This attribute, coupled with their lower emission of toxic substances during incineration, positions biodegradable plastics as an eco-friendly substitute for their non-degradable counterparts. In addition, the utilization of biomass in the production of bioplastics underscores a shift towards renewable resources, contributing to the

reduction of carbon emissions and further aligning with principles of sustainability [8]. Despite these promising attributes, the application of biodegradable plastics as a panacea for environmental challenges, particularly marine pollution, is not without limitations. The efficacy of biodegradation is contingent upon specific environmental conditions [9], such as adequate temperature, moisture, and oxygen levels, which are not universally present in natural settings. Thus, this characteristics can raise questions about how reliably biodegradable plastics can consistently and effectively address issues like marine litter, where conditions for biodegradation may not be optimal. Moreover, the adoption and integration of biodegradable plastics into existing waste management systems necessitate careful consideration [10]. Additionally, the economic implications of transitioning to biodegradable plastics, including production costs and market acceptance, warrant thorough evaluation to assess their feasibility as a sustainable alternative on a global scale [11]. As a consequence, the exploration of biodegradable plastics' possibilities and limitations becomes a crucial area of inquiry. The exploration of biodegradable plastics, encompassing their potential benefits and inherent limitations, has become a topic of significant interest and debate within society [12]. This discourse profoundly influences policy-making processes, consumer behaviors, and the trajectory of industrial innovation. In the context of South Korea, discussions surrounding biodegradable plastics are notably vibrant within media channels, playing a pivotal role in shaping public perceptions and informing policy directions. Media narratives and debates essentially act as a barometer for societal attitudes towards this critical environmental issue, providing insights into collective values and priorities [13].

The role of media in framing the dialogue around biodegradable plastics cannot be overstated. By highlighting certain aspects, challenges, and breakthroughs, the press has the power to mobilize public opinion, advocate for sustainable practices, and potentially sway the direction of governmental and corporate policies [14]. The narrative constructed by media outlets can emphasize the ecological benefits of biodegradable plastics, such as reduced dependency on fossil fuels and minimized impact on wildlife, or conversely, spotlight the challenges, including the complexities of disposal and the risk of misleading claims about biodegradability [12-14]. However, the depth and breadth of media influence on shaping perceptions of biodegradable plastics remain underexplored. While it is clear that the media plays a foundational role in disseminating information and generating discourse, the extent to which this discourse translates into positive or negative perceptions among the general public, policymakers, and industry stakeholders is less understood [13]. Furthermore, the nuances of media coverage, including the balance between optimism and skepticism, the accuracy of presented information, and the prevalence of certain themes over others warrant a more comprehensive analysis [14].

This gap in understanding underscores the necessity for systematic research into the media's portrayal of biodegradable plastics and its impact on societal attitudes, which could not only elucidate the dynamics of public discourse, but also offer valuable insights into how media coverage aligns with or diverges from scientific understandings and industry practices. Therefore, this study aims to investigate the scope and nature of societal interest in biodegradable plastics as presented in the South Korean media, utilizing big data analysis of news articles. Specifically, the study aims to analyze the distribution of topics, frequency of mentions, and trends over time in news content to gain a deeper understanding of societal perceptions and the discourse surrounding biodegradable plastics. Through this analysis, the research intends to provide foundational data essential for assessing the sustainable use possibilities of biodegradable plastics and their environmental, social, and economic impacts. Furthermore, this study is expected to contribute to shaping public awareness regarding biodegradable plastics and offer insights into the implications for policy-making and industrial development directions.

2. LITERATURE REVIEW

2.1. Biodegradable Plastics

Biodegradable plastics are engineered to allow microorganisms in the environment to metabolize the molecular structure of the plastic material, leading to decomposition [15]. Biodegradable plastics represent a significant advancement in the development of environmentally conscious materials [16]. Engineered to decompose through the metabolic processes of microorganisms, these plastics undergo a transformation that mitigates their long-term impact on ecosystems. The biodegradation process entails the breakdown of complex plastic polymers into simpler molecules that microbes can consume, ultimately converting these materials into natural substances like water, carbon dioxide, and compost. Biodegradable plastics can offer a solution to this problem by integrating naturally occurring substances into their molecular structure, which can include polymers derived from plant starches such as corn, sugarcane, or potato [17]. These bio-based materials are not only renewable, owing to their plant origins, but they also tend to require less energy to produce and generate fewer greenhouse gases during degradation compared to traditional petroleum-based plastics. In addition to starch-based polymers, the production of biodegradable plastics can also utilize other natural polymers like cellulose, chitosan, and PLA, which is derived from fermented plant sugars [18]. The diversity of these base materials allows for the creation of plastics with a range of properties and applications, from rigid containers to flexible films. The environmental benefits of biodegradable plastics are further enhanced when considering the end-of-life scenarios for these materials [19]. Ideally suited for organic recycling processes, such as industrial composting facilities, these plastics can be returned to the earth without leaving toxic residues. This cycle of use and return to nature illustrates a closed-loop system, aligning with the principles of a circular economy and reducing the accumulation of waste in landfills and oceans. However, it is crucial to understand that biodegradable plastics require specific conditions to decompose effectively, which are not always present in natural settings. Temperature, humidity, and microbial activity levels are critical factors that influence the rate of decomposition. Therefore, the proper disposal and processing of biodegradable plastics are essential to ensure that they provide their intended environmental benefits [20]. As the technology and application of biodegradable plastics evolve, there is a growing need for regulatory frameworks to ensure product claims of biodegradability are accurate and standardized [21]. Consumer awareness and understanding of how to dispose of these materials correctly are also vital in maximizing their positive environmental impact. Recognizing the environmental hazards of traditional plastic accumulation, scientists have been exploring various biodegradable alternatives such as PLA and Polyhydroxybutyrate (PHB). Furthermore, PHB is a prominent, fully biodegradable form of plastic produced naturally by bacteria and archaea, consisting of R-3-hydroxybutyrate monomers [22]. Its similarity to conventional plastics makes it a practical candidate for broad application and mass production, potentially replacing existing non-biodegradable plastics. A recent advancement involves using response surface methodology (RSM) with central composite design (CCD) to enhance PHB synthesis, significantly increasing its yield. RSM, through CCD optimization, has proven to boost PHB production by 1.4 times compared to traditional methods, marking a breakthrough in the efficient manufacturing of eco-friendly plastics [23].

2.2. Microorganisms Involved in Biodegradation

The process of biodegradation of plastics is a complex interplay between microorganisms and polymeric materials designed to undergo decomposition in natural environmental settings [24]. It is an orchestrated event facilitated predominantly by specific strains of bacteria and fungi. Corynebacterium glutamicum is a facultative anaerobic bacterium that is widely used in the

production of amino acids, such as L-glutamate and L-lysine [25]. Corynebacterium glutamicum produces a wide variety of chemical substances in both aerobic and anaerobic conditions. The growth and production of organic acids through the metabolism of the bacterium depend on the oxygen level [26]. Under certain conditions, it produces organic acids like L-lactate and succinate, which are necessary compounds for the formation of bio-based plastic monomers. Researchers have shown that by modifying metabolic pathways or providing alternative electron acceptors in place of oxygen, anaerobic cell growth with L-lysine production and aerobic succinate production can be achieved [25]. These microorganisms are equipped with a suite of enzymes capable of catalyzing the breakdown of long-chain polymer molecules, which constitute the structure of plastics, into smaller, more manageable compounds. These compounds are subsequently assimilated by the microorganisms as sources of energy and nutrients, integral for their growth and reproduction. Enzymatic biodegradation is a sophisticated process: each enzyme exhibits specificity for certain bond types found within the polymeric chains. For example, esterases and lipases can target the ester bonds common in aliphatic polyesters such as PLA, while other enzymes like cutinases may be involved in degrading more complex structures [27]. As a result, the microorganisms play a pivotal role in the material's life cycle, breaking it down into fundamental components such as water, carbon dioxide, methane in anaerobic conditions, and biomass – effectively returning the carbon back to the ecological cycle. The rate and extent of biodegradation, however, are not solely dependent on the presence of these microorganisms but are significantly influenced by a myriad of factors. The type of microorganism is a fundamental factor, different species produce different enzymes and have varying capabilities to degrade different types of plastics. Furthermore, environmental conditions such as temperature, pH, oxygen levels, and the presence of other nutrients or microorganisms can either accelerate or inhibit the biodegradation process [28]. The chemical structure of the plastic itself also plays a crucial role. Polymers may be designed with particular functional groups that are more readily attacked by enzymes or may contain additives that either promote or impede microbial activity. Additionally, the physical properties of the plastic, such as crystallinity, surface area, and the presence of plasticizers or other additives, can affect the accessibility of the enzymes to the polymer chains and the biodegradation rate [5]. A higher crystallinity, for instance, often leads to reduced biodegradation rates due to the more tightly packed molecular structure, which is less accessible to microbial attack. Understanding the complex relationships between microorganisms and the plastics they degrade is essential for advancing the field of biodegradable plastics. Thus, Liu et al. [28] focused on identifying and engineering microorganisms with enhanced biodegradation capabilities, developing new plastics with optimized chemical structures for biodegradation, and improving our understanding of how environmental factors influence these processes.

3. MATERIALS AND METHODS

3.1. Bigkinds

The BIGKinds platform, developed by the Korea Press Foundation, was utilized to collect and analyze data related to biodegradable plastics, environmental pollution, and their associated pros and cons [29]. BIGKinds offers a comprehensive big data analysis service through an integrated database, which aggregates news articles from various media outlets [30]. This platform enables researchers to conduct in-depth analyses by providing access to a vast array of information from newspapers, broadcast stations, and other media sources. The BIGKinds service is particularly useful for studies like this one, where the goal is to understand trends and patterns over an extended period [31].

3.2. Data Collection

The data collection for this study was conducted over a decade, from January 1, 2014, to December 31, 2023 (Table 1). During this period, data were gathered from 104 major national media outlets in South Korea, encompassing newspapers, broadcast stations, and other significant sources of news. The comprehensive nature of this data collection effort ensured that a wide variety of perspectives and information related to biodegradable plastics were included in the analysis. The process involved several steps to ensure the thoroughness and accuracy of the collected data. Initially, the BIGKinds platform was used to identify relevant articles based on specific keyword “biodegradable plastics” in Korean.

Table 1. Conditions for searching for articles

Keyword	Data collection	Media data
Biodegradable plastics	Jan 1, 2014 - Dec 31, 2023	Articles from 104 media outlets in South Korea, including broadcasters like KBS and newspapers like Donga Ilbo

3.3. Data Analysis

The data analysis phase of this study focused on two primary aspects: the frequency of articles mentioning biodegradable plastics and the analysis of related keywords. The analysis was conducted using data collected over the ten-year period.

4. RESULTS

4.1. Frequency of Keywords

From Jan 1, 2014 to Dec 31, 2023, a cumulative count of 4,403 articles discussing biodegradable plastics was documented in the South Korean media. The breakdown of articles by year is as follows: 26 in 2014, 16 in 2015, 17 in 2016, 26 in 2017, 99 in 2018, 289 in 2019, 605 in 2020, 1,474 in 2021, 1,057 in 2022, and 794 in 2023.

4.2. Keyword Trend

The keyword "biodegradable plastic" saw a consistent increase in media attention from 26 articles in 2014 to 1,474 articles in 2021, indicating sustained interest in biodegradable plastics. However, there was a gradual decline observed in subsequent years, with 1,057 articles in 2022 and 794 articles in 2023.

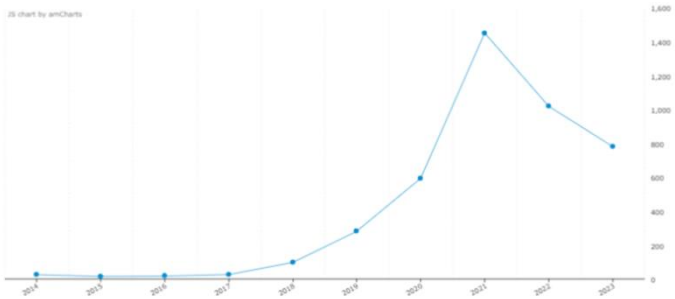

Figure 1. Trend analysis

4.3. Analysis of Related Keywords

The analysis of related keywords provides comprehensive insights into discussions surrounding biodegradable plastics and their associated concepts. Table 2 shows a detailed breakdown of the top 10 related keywords. The analysis of related keywords in Table 1 provides significant insights into the discourse surrounding biodegradable plastics and their associated concepts. The table ranks the top 10 related keywords based on their weight and frequency, highlighting the most discussed topics in this field. At the top of the list is "Eco-friendly," with the highest weight of 131.92 and a frequency of 3,431, indicating its paramount importance and frequent mention in discussions. Following closely are "PHA" with a weight of 120.64 and a frequency of 1,498, and "PLA" with a weight of 101.79 and a frequency of 1,001. These keywords underscore the emphasis on specific biodegradable plastic materials. "Recycle" ranks fourth, with a weight of 92.59 and a frequency of 1,115, reflecting the ongoing focus on recycling practices in the context of biodegradable plastics. "Package" and "Microorganism" follow, with weights of 89.37 and 74.06, and frequencies of 1,265 and 518, respectively, indicating the relevance of packaging solutions and the role of microorganisms in biodegradation processes. "Commercialization" is seventh, with a weight of 65.01 and a frequency of 447, highlighting the discussions on bringing biodegradable plastics to market. "PBAT" (Polybutylene Adipate Terephthalate) is next, with a weight of 42.55 and a frequency of 642, followed by "Cosmetic container" with a weight of 38.95 and a frequency of 221, and "LMEX" with a weight of 20.74 and a frequency of 139. Overall, these keywords reflect the diverse aspects and focal points in the field of biodegradable plastics, ranging from materials and processes to applications and commercialization.

Table 2. Related Keywords

Rank	Keywords	Weight	Frequency
1	Eco-friendly	131.92	3,431
2	PHA	120.64	1,498
3	PLA	101.79	1,001
4	Recycle	92.59	1,115
5	Package	89.37	1,265
6	Microorganism	74.06	518
7	Commercialization	65.01	447
8	PBAT	42.55	642
9	Cosmetic container	38.95	221
10	LMEX	20.74	139

4.4. Discussion

Biodegradable plastics present numerous possibilities that make them a promising alternative to conventional plastics. Their potential can be explored through three primary aspects: environmental benefits, versatility in production, and alignment with sustainability principles. First, one of the most significant possibilities of biodegradable plastics is their environmental benefit. Unlike traditional plastics that persist in the environment for hundreds of years, biodegradable plastics decompose into natural substances like water, carbon dioxide, and biomass through microbial action. This decomposition process, facilitated by bacteria, fungi, and algae reduces the long-term environmental impact of plastic waste. For instance, Shah et al. [32] highlighted that biodegradable plastics significantly reduce the accumulation of waste in landfills and oceans, mitigating the adverse effects on wildlife and marine ecosystems. Additionally, biodegradable plastics emit fewer toxic substances during incineration compared to conventional

plastics, which reduces air pollution and associated health risks. Second, the versatility in the production of biodegradable plastics adds to their appeal as a sustainable alternative. These plastics can be derived from a diverse array of raw materials, including both biomass and fossil fuel-based compounds. For example, PLA is produced from fermented plant sugars, such as corn, sugarcane, and potato starch. Similarly, PHAs are produced through bacterial fermentation of sugars and lipids. This versatility allows for the creation of biodegradable plastics with varying properties suitable for different applications, from rigid containers to flexible films. Brodin et al. [33] demonstrated that the ability to use various feedstocks enhances the adaptability of biodegradable plastics, making them suitable for a wide range of industrial applications. Third, biodegradable plastics align with sustainability principles by promoting the use of renewable resources and reducing carbon emissions. The production of bioplastics from renewable biomass sources such as agricultural residues, forestry by-products, and food waste supports a circular economy. According to Narancic et al. [34], using biomass in bioplastic production not only reduces dependency on fossil fuels but also contributes to the reduction of greenhouse gas emissions. Additionally, biodegradable plastics can be composted under appropriate conditions, reintegrating into the ecological cycle without leaving harmful residues. This attribute positions biodegradable plastics as an eco-friendly substitute for their non-degradable counterparts, supporting sustainable materials management and environmental conservation efforts. Despite their promising attributes, biodegradable plastics face several limitations that challenge their efficacy and widespread adoption. These limitations include dependency on specific environmental conditions, integration into existing waste management systems, and economic feasibility. First, the efficacy of biodegradation for biodegradable plastics is highly contingent upon specific environmental conditions such as adequate temperature, moisture, and oxygen levels. In natural settings, these conditions are not always present, which can hinder the decomposition process. Kyrikou and Briassoulis [35] found that biodegradable plastics often fail to degrade effectively in environments lacking the necessary microbial activity and environmental conditions. This limitation raises questions about how reliably biodegradable plastics consistently and effectively address issues like marine litter, where conditions for biodegradation may not be optimal. Second, the adoption and integration of biodegradable plastics into existing waste management systems necessitate careful consideration. Current waste management infrastructures are designed primarily to handle conventional plastics and may not be equipped to process biodegradable plastics effectively. Third, the economic implications of transitioning to biodegradable plastics are another significant limitation. The production costs of biodegradable plastics are generally higher compared to conventional plastics, which can hinder their market acceptance and feasibility as a sustainable alternative. According to a study by Aeschelmann and Carus [36], the high production costs are primarily due to the expensive raw materials and complex manufacturing processes involved in producing biodegradable plastics. Furthermore, the market for biodegradable plastics is still developing, and consumer awareness and demand are relatively low, which affects the economies of scale necessary to reduce costs. This economic challenge necessitates thorough evaluation to assess the feasibility of biodegradable plastics on a global scale. Therefore, while biodegradable plastics offer significant environmental benefits, including versatility in production, and alignment with sustainability principles, their dependency on specific environmental conditions, challenges in integration into existing waste management systems, and economic feasibility pose substantial limitations. Understanding these possibilities and limitations is crucial for advancing the development and adoption of biodegradable plastics as a viable solution for sustainable materials management.

5. CONCLUSIONS

This study provides a comprehensive analysis of the trends and patterns in media coverage related to biodegradable plastics in South Korea over a ten-year period, utilizing the BIGKinds platform for data collection and analysis. The results indicate a significant increase in media

attention towards biodegradable plastics, peaking in 2021 with a notable decline in subsequent years. The keyword analysis reveals that discussions surrounding biodegradable plastics are multifaceted, focusing on environmental benefits, specific materials like PHA and PLA, and concepts such as recycling and commercialization. The findings highlight the growing public and media interest in biodegradable plastics as a viable solution to environmental pollution caused by conventional plastics. The steady rise in articles up until 2021 suggests a heightened awareness and advocacy for sustainable materials among the media and possibly the general public. However, the decline in articles post-2021 indicates a need for continued engagement and discourse to maintain momentum and support for biodegradable plastics. The keyword analysis underscores the importance of various aspects in the discourse on biodegradable plastics. Terms like "Eco-friendly," "Recycle," and "Commercialization" reflect a broad concern with not just the environmental impact but also the practical implementation and market viability of these materials. The emphasis on specific materials like PHA and PLA points to ongoing research and development in creating effective and versatile biodegradable plastics.

Despite the promising trends, the study also identifies several challenges that need to be addressed. The dependency on specific environmental conditions for effective biodegradation, integration into existing waste management systems, and economic feasibility are significant hurdles. These challenges highlight the necessity for further research and development, policy support, and public education to foster a more conducive environment for the adoption of biodegradable plastics. While biodegradable plastics offer substantial potential in mitigating environmental pollution and aligning with sustainability goals, their successful implementation depends on overcoming the identified challenges. Continued media engagement, along with coordinated efforts from policymakers, industry stakeholders, and the public is crucial to advancing the development and adoption of biodegradable plastics. This study contributes valuable insights into the evolving discourse on biodegradable plastics and sets the stage for future research and initiatives aimed at promoting sustainable materials management.

ACKNOWLEDGEMENTS

The authors would like to thank Dr. Austin Kang for his valuable advice in completing the paper.

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