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The Development of Bioplastic Research as an Alternative to Conventional Biodegradable Plastics: Bibliometric Analysis

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Abstract. The increase in consumerism and the limited public awareness of plastic use has resulted in significant plastic waste accumulation in the coastal areas of the Riau Islands. A notable example is a 3.5-metre-high pile of waste on Senggarang Beach, and Batam's daily waste production reaching 1,200 tonnes, with limited landfill capacity. This study conducts a bibliometric analysis, aiming to identify publication trends and citation patterns in bioplastic research from 2020 to 2025 to understand the growth dynamics and scientific impact of this field. A bibliometric analysis of 990 bioplastic publications (2020–2025) with 49,801 citations and an h-index of 105 shows the evolution of research from the characterisation of basic materials such as starch and cellulose to the exploration of innovative raw materials including food waste and microalgae. Density analysis reveals that the concept of “bioplastic” has the highest research intensity, with significant associations to plastic, bio, PLA, and biopolymers, as well as practical applications such as food packaging and mechanical properties. Temporal patterns show that the concepts of bioplastic production, microalgae, and degradation emerged as significant research areas in 2022. This marks a paradigm shift in research toward sustainable production processes and enhanced biodegradability as solutions to the conventional plastic crisis.

Introduction

Coastal areas are transitional areas between land and sea with abundant resources (Mykhailyk, 2024). These coastal areas have a variety of ecosystems that are sensitive to various impacts of natural factors and anthropogenic processes according to the complexity of their dynamic exchanges with the terrestrial environment. The ecosystems in this area include estuaries, deltas, lagoons, mangrove wetlands, beaches, seagrass beds, and coral reefs (Lakshmi, 2021). The many natural resources stored within these ecosystems have fueled rapid economic, social and developmental growth in the coastal zone.

This growth is often linear with social and lifestyle changes. Consumptive lifestyles and dependence on single-use plastic products have also increased, resulting in

environmental pollution problems (Nuraiti Tengku Izhar & Voon May, 2020). Not to mention, the level of public awareness of the environment regarding the use and processing of plastics is still low, adding to the serious pollution problem (Herdiansyah, Sholihah, & Frimawaty, 2022). The problem of plastic pollution in coastal areas can be seen in the accumulation of plastic waste in the Riau Islands. This pile of garbage has reached 3.5 meters on the shoreline of Senggarang according to the statement of the Pemerintah Provinsi Kepulauan Riau (2021). Not only that, there is still a lot of garbage that cannot be netted, so that it is carried away by waves and currents due to sea tides. In addition, in Batam City, waste generated reaches 1,200 tons/day and only around 900-1,000 tons can end up in the Telaga Punggur landfill (Wiyoga, 2024).

As a result of this poor plastic waste management, microplastics were found in marine biota in the Riau Islands. Microplastics are small pieces of plastic less than 5 mm in size, which can be potentially harmful to health

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(Jung et al., 2022), such as oxidative stress and tissue necrosis (Sunday, 2021). This microplastic problem can be proven by one of the studies (Simanjuntak, 2023) of which states that the highest total abundance of microplastics is at Teluk Bakau station, in *Strombus* sp. amounting to 227.60 particles/g and in sediments with an average of 1005.83 particles/g.

Seeing these conditions, a promising solution is needed to overcome this problem in the form of developing bioplastics as an alternative to conventional plastics. Bioplastics are a type of plastic derived from natural polymers that easily decompose back into carbon dioxide (Sidek, Draman, Abdullah, & Anuar, 2019). This is because bioplastics have biodegradable properties, which means they can be broken down by natural microorganisms into compounds that are not harmful to the environment.

This study involved conducting a bibliometric analysis by investigating and collecting literature data. The aim of this analysis is to identify publication trends and citation patterns in bioplastic research between 2020 and 2025, in order to understand the growth dynamics and scientific impact of this field. Using VOSviewer and comprehensive citation metrics for a systematic bibliometric analysis, this study is expected to contribute accurate knowledge landscape mapping, the identification of research gaps requiring further exploration and the provision of a research roadmap for bioplastics to support the development of more innovative, applicable, sustainable plastic solutions

Result and Discussion

Research Data Matrix

The present research database was compiled with the assistance of Publish or Perish, published in Google Scholar. The publication period under consideration was from 2020 to 2025 are presented in Table 1. Meanwhile, the publications most frequently cited in the relevant fields are presented in Table 2.

As illustrated in Table 1, an overview of the performance of scientific publications related to bioplastic research in the 2020-2025 period is provided. The database contains 990 papers, with a total of 49,801 citations, averaging 9,960.20 citations per year and 50.30 citations per paper. This finding suggests that research in the field of bioplastic has a substantial scientific impact, which is in line with the productivity of the authors, who have an average of 293.79 papers per author and an average of 3.98 authors per paper.

The research data matrix also includes an h-index of 105 and a g-index of 172. An h-index of 105 signifies that there are 105 papers, each of which has been cited a minimum of

105 times, thereby indicating the presence of highly influential core publications. A higher g-index is indicative of a paper's significant contribution to the total citations, owing to the large number of citations it has received. Furthermore, the standardisation of the publication period is evident from the h1.norm value of 49 and h1,annual of 9.80.

The hA-index value of 9.90 indicates the number of papers that have reached a certain citation threshold after normalising the publication age. A distinctive characteristic of this study is the presence of numerous papers with remarkably elevated Altmetric Attention Scores (ACC), specifically values of $\geq 1, 2, 5, 10, 20$, with particular values of 976, 927, 722, 456, and 219. This finding suggests that the majority of publications (976 out of 990 papers) garnered attention, with 219 papers attaining an altmetric score of ≥ 20 . This figure illustrates the broad impact on both the academic community and the general public.

VOSViewer Visualization

Using the VOSViewer application, three data maps were obtained to observe the development of research on coconut fibre-based bioplastics. In the network visualization and overlay visualization data maps, there are two elements that provide insight: nodes and edges. The node element, represented by a circle, indicates the frequency of articles in the database, as seen from the title and abstract. Meanwhile, the edge element indicates the relationship and strength between nodes. The closer the distance between nodes and keywords, the stronger the relationship between those nodes or keywords (Aribowo, 2019).

Based on Figure 1, the network map indicates the relationships between concepts in the field of bioplastics and sustainable materials. The network structure depicts three main clusters distinguished by different colours. The first cluster, coloured green on the left, focuses on sustainability and environmental aspects, with the central node being 'bioplastics.' Additionally, the keywords in this cluster are 'sustainability,' 'environment,' 'petroleum,' 'plastic,' 'bio,' and 'biopolymer.' This cluster also includes concepts related to bioplastic production, such as 'bioplastic production,' 'food waste,' 'microalgae,' and 'degradation,' which also highlight a focus on alternative raw materials and the biodegradable properties of bioplastics.

Furthermore, the red cluster on the right focuses on technical aspects and applications with several nodes. These nodes are related to bioplastic raw materials, synthesis processes, and the resulting materials. The nodes in question are 'starch,' 'cellulose,' 'film,' 'synthesis,' 'property,' 'mechanical property,' and 'characteristic.' For

practical applications, the related nodes are 'food packaging' and 'plasticizer.'

The third cluster, smaller in size and coloured blue, is located at the bottom. The nodes in this cluster contain more specific chemical terms such as 'polylactic acid' (PLA) and 'polyhydroxyalkanoate' (PHA). The chemical terms used represent types of bioplastics.

In Figure 2, the development of research topics can be analysed based on publication year. Yellow represents newer concepts (closer to 2022), while blue and green represent earlier concepts within that period.

The central node, entitled 'bioplastic', which is of the largest size, indicates its position as the core concept which connects the entire research network. A close examination of the main node reveals a distribution of concepts that demonstrate an intriguing temporal evolution. Concepts such as 'bioplastics production,' 'microalgae,' 'food waste,' and 'degradation,' coloured yellow, indicate that these topics became the focus of more intensive research towards the end of 2021 and the beginning of 2022. This development corresponds with an emerging research trend towards the exploration of alternative raw materials and more sustainable production processes.

Concurrently, technical concepts such as 'starch,' 'cellulose,' 'film,' 'mechanical property' and 'synthesis' demonstrate a colour gradient from green to blue, thereby signifying that research on material characterisation and the mechanical properties of bioplastics has become a well-established foundation in previous periods. Application clusters encompassing 'food packaging,' 'property,' and 'characteristic' also exhibit diverse colours, indicating continuity in research from fundamental aspects to practical applications. It is noteworthy that concepts such

as 'polyhydroxyalkanoate' (PHA) and 'polylactic acid' (PLA) are represented in blue, signifying that these particular types of bioplastics have attained a status of established research focus.

Furthermore, Figure 3 displays a density visualization, or density map, generated by VOSviewer to analyse the distribution and intensity of research in the field of bioplastics. The visualisation employs a heat map, utilising colour gradations from dark blue (low density) to bright yellow (high density), thereby providing an intuitive overview of the most intensive and productive areas of research in the analysed literature corpus.

The 'bioplastic' node demonstrates the highest intensity, exhibiting a bright yellow colour that confirms its position as the most frequently appearing central concept with the strongest connections in the research network. The area surrounding this primary node exhibits a green-yellow gradient, indicative of closely related concepts such as 'plastic,' 'bio,' "pla" (polylactic acid), and 'biopolymer.' These concepts demonstrate high density, reflecting an intensive research focus on fundamental materials and specific categories of bioplastics.

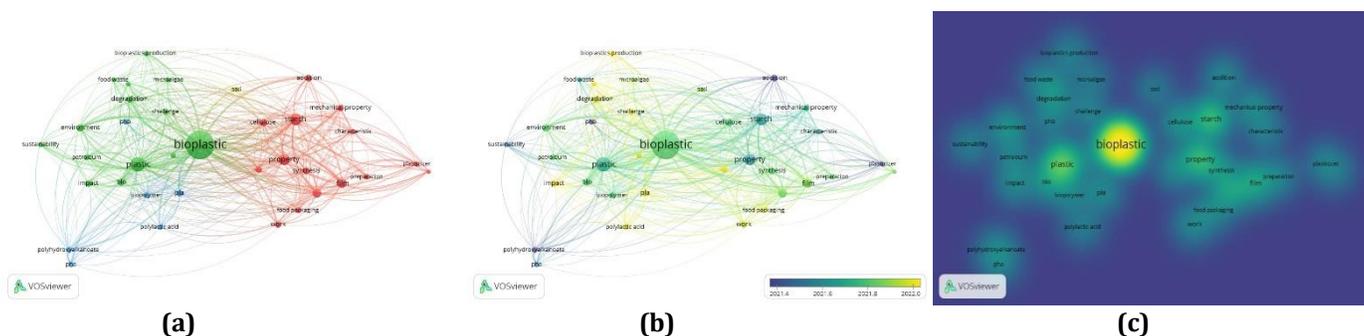
The medium-to-high density area (green-cyan colour) encompasses concepts such as 'starch,' 'cellulose,' 'property,' 'synthesis,' and 'film,' thereby signifying that research on the primary raw materials of bioplastics (starch and cellulose), material property characterisation, synthesis processes, and applications in film form is receiving substantial attention. Application areas such as 'food packaging' and technical concepts like 'mechanical property' and 'characteristic' also demonstrate relatively high density, indicating active research in the development of practical bioplastic applications.

Table 1. Research data matrix.

Publication years	: 2020 – 2025
Citation years	: 5 (2020 – 2025)
Papers	: 990
Citations	: 49801
Cites/year	: 9960.20
Cites/paper	: 50.30
Cites/author	: 14374.24
Papers/author	: 293.79
Authors/paper	: 3.98
h-index	: 105
g-index	: 172
hI,norm	: 49
hI,annual	: 9.80
hA-index	: 51
Papers with ACC	: 1,2,5,10,20:976,927,722,456,219

Table 2. Most frequently cited publication.

Citations	Reference	Title
1600	(Rosenboom, Langer, & Traverso, 2022)	Bioplastics for a circular economy
827	(Meereboer, Misra, & Mohanty, 2020)	Review of recent advances in the biodegradability of polyhydroxyalkanoate (PHA) bioplastics and their composites
625	(Mujtaba et al., 2023)	Lignocellulosic biomass from agricultural waste to the circular economy: a review with focus on biofuels, biocomposites and bioplastics
586	(Asgher, Qamar, Bilal, & Iqbal, 2020)	Bio-based active food packaging materials: Sustainable alternative to conventional petrochemical-based packaging materials
553	(Xia et al., 2021)	A strong, biodegradable and recyclable lignocellulosic bioplastic
468	(RameshKumar, Shaiju, O'Connor, & P, 2020)	Bio-based and biodegradable polymers-State-of-the-art, challenges and emerging trends
449	(Folino, Karageorgiou, Calabrò, & Komilis, 2020)	Biodegradation of wasted bioplastics in natural and industrial environments: a review
446	(Atiweh, Mikhael, Parrish, Banoub, & Le, 2021)	Enviromental impact of bioplastic use: a review
443	(Inamuddin & Altalhi, 2022)	Handbook of Bioplastics and Biocomposites Engineering Applications
429	(Chia, Ying Tang, Khoo, Kay Lup, & Chew, 2020)	Nature's fight against plasctic pollution: algae for plastic biodegradation and bioplastics production

**Figure 1.** (a) Network Visualization (b) Overlay Visualization (c) Density Visualization.

Concepts located at the periphery of the map and characterised by a more dominant blue colour, such as 'polyhydroxyalkanoate' (PHA), 'sustainability,' 'environment,' 'petroleum,' and 'challenge,' demonstrate lower density yet maintain relevance within the bioplastic research ecosystem. This density distribution pattern provides insights into core areas and emerging areas in research. High-density areas represent established mainstream research topics, while low-density areas may represent niche areas or emerging research directions with potential for future development.

Conclusion

This study is based on a bibliometric analysis of 990

publications on bioplastics from 2020 to 2025. These publications generated 49,801 citations, and together have an h-index of 105. The study reveals the dynamics of the development of bioplastics as a sustainable alternative to conventional plastics. Network visualisation illustrates the evolution of research, from its initial focus on the characterisation of fundamental materials such as starch and cellulose, towards the exploration of more innovative alternative raw materials, including food waste and microalgae. This reflects a growing research trend in the direction of the circular economy and sustainability. Density analysis indicates that the concept of 'bioplastic' exhibits the highest level of research intensity, with significant associations to plastic, bio, PLA, and

biopolymer. Furthermore, practical applications such as food packaging and mechanical properties demonstrate substantial research density. Temporal patterns indicate that concepts such as bioplastics production, microalgae, and degradation are emerging as significant research areas by 2022, signalling a shift in research paradigms from material characterisation towards sustainable production processes and biodegradability enhancement. This marks the maturation of the bioplastics field as a viable solution to address the conventional plastic crisis.

Conflict of Interest

The authors declare that there is no conflict of interest.

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