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Systematic literature review: Feasibility of replacing conventional polymers with biopolymers in the food packaging sector.

Systematic Literature Review: Feasibility of Replacing Conventional Polymers with Biopolymers in the Food Packaging Sector.

Systematic literature review: feasibility of replacing conventional polymers with biopolymers in the food packaging sector.

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Summary

Conventional polymers are widely used in the food packaging industry.
Due to factors such as low cost, versatility, and resistance, these materials generate a large amount of waste and have a prolonged degradation time, which harms the environment. Thus, biopolymers emerge as a sustainable alternative to materials of fossil origin. This study aims to analyze the technical, economic, and environmental aspects of biopolymers in the food packaging sector, with a view to replacing conventional polymers with biodegradable materials. The methodology used was a systematic literature review, with searches in databases such as Scopus, Web of Science, Elsevier, and Google Scholar, limited to studies published between 2021 and 2025. After applying the inclusion and exclusion criteria, 13 studies were selected for qualitative analysis. With the results obtained, it can be verified, through the analysis, that biopolymers present several advantages: biodegradability, use of renewable raw materials, and reduction of solid waste. It was also observed that materials such as PLA (polylactic acid), starch, cellulose, and chitosan have great potential for application in biodegradable packaging; However, barriers related to material strength, moisture sensitivity, thermal stability, and production costs still exist. Therefore, biopolymers are a promising alternative to conventional polymers; however, technological advancements, process improvements, and greater economic viability are still needed to expand their application to a large industrial scale.

Keywords: Biopolymers, Sustainable packaging, Biodegradable polymers, Sustainability, Food packaging.

Abstract

Conventional polymers are widely used in the food packaging industry due to their low cost, versatility, and strength. However, they generate a large amount of waste and have a long degradation time, harming the environment. Thus, biopolymers emerge as a sustainable alternative to fossil-based materials. This study aims to analyze the technical, economic, and environmental aspects of biopolymers in the food packaging sector to replace conventional polymers with biodegradable materials. The methodology used was a systematic literature review, searching databases such as Scopus, Web of Science, Elsevier, and Google Scholar, limiting the search to studies published between 2021 and 2025. After applying the inclusion and exclusion criteria, 13 studies were selected for qualitative analysis. Based on the results obtained, the analysis shows that biopolymers have several advantages: biodegradability, use of renewable raw materials, and reduction of solid waste. It was also observed that materials such as PLA (polylactic acid), starch, cellulose, and chitosan have great potential for application in biodegradable packaging. However, there are still barriers related to material resistance, humidity sensitivity, thermal stability, and production costs. Thus, it is clear that biopolymers are a promising alternative to conventional polymers, but technological advances, process improvements, and greater economic viability are still needed to expand their industrial applications.

Keywords: Biopolymers, Sustainable packaging, Biodegradable polymers, Sustainability, Food packaging.

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1. Introduction

Plastics made from conventional polymers, such as polyethylene (PE), polypropylene (PP), and polyethylene terephthalate (PET), are widely used in the packaging industry and play an essential role in society; they are present in various daily activities, especially in the storage of food and personal hygiene products, due to characteristics such as lightness, malleability, flexibility, and resistance to microbial agents, as well as the rate of degradation. In recent years, there has been a growing trend in the production and consumption of plastics, accompanied by a significant increase in the generation of waste resulting from disposal. This scenario is driven, above all, by low production costs and the linear economic model, which favors its widespread application in disposable products. As a consequence, there is an accumulation of waste that persists in the environment, causing negative impacts on the ecosystem and human health (TAMBURINI *et al.* 2021).

Given this context, the development and commercialization of equally viable alternative materials, such as biodegradable and bio-based polymers, become necessary (ROSENBOOM; LANGER; TRAVERSO, 2022).
The factors discussed above justify the need for studies focused on replacing conventional polymers with bio-based polymers, aiming to change global culture in order to produce a less polluted and cleaner environment for society in the future, without affecting daily practices.

For this change in mindset to occur efficiently, it is necessary to understand the classifications and applications of biopolymers studied in the scientific literature. According to Jin and Spontak (2023), bio-based polymers are classified as green materials,
Obtained from natural raw materials, it is necessary to map and select relevant studies addressing the replacement of conventional polymers with biopolymers in the packaging sector that are representative (last 5 years), compare the technical and environmental performance of biopolymers with conventional polymeric compounds based on the literature, and also analyze the main factors influencing this viability, such as cost, raw materials, industrial scalability, and market acceptance, identifying gaps and opportunities for future research related to the implementation of biopolymers in sustainable packaging. Eventually, with these objectives defined, it facilitates the understanding of the current applicability and scale of industrial production, as well as the comparative advantages of the product life cycle and the environmental impacts generated.

Therefore, the study of biopolymers is justified due to the environmental impacts of conventional polymers, as well as the concept of a circular economy, which is becoming increasingly important, aiming at the reuse of natural resources in new productive segments, integrating industry, the economy and society (SATIE; CARVALHO; ROEDER, 2021).
Considering the factors discussed, the substitution of biopolymers in the food industry has been identified as a more sustainable alternative, given that the food industry is a vital factor for human development, operates on a large scale, and requires packaging for the protection and handling of food, which generates high demand for packaging currently manufactured from conventional polymeric compounds.

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2. Theoretical Framework

2.1. Conventional polymers and biopolymers

Conventional polymers are currently essential in food packaging due to their versatile properties, being either flexible or rigid, as well as their low production cost. They also possess excellent barrier properties against external agents and ease of processing due to their high moldability. The main challenge today is plastic waste, which has a high volume demanded by the packaging sector and slow degradation, taking more than 400 years, causing exorbitant and accumulated pollution throughout the product's life cycle. Therefore, more research is needed to explore new and better technologies, aiming to accelerate plastic degradation or reduce waste production in order to mitigate the potential environmental impact resulting from the generation of conventional polymer waste (BABAREMU; OLADIJO; AKINLABI, 2023).

As a means of solving these challenges, especially the cumulative factor, biopolymers show great potential, as they bring benefits to sustainable development by reducing the product life cycle, thus avoiding the excessive accumulation of waste in the environment. The idea of biopolymers arose from the discovery of new uses for fruit and plant waste, already commonly used in the food industry, but without reuse, which reinforces the concept of a circular economy and promotes gains for the environment, industry, and society (PINTO, 2022). They have gained visibility in the packaging industry for being ecological and sustainable, constituting a proposal to replace traditional plastics derived from fossil fuels, in addition to helping reduce the environmental impact of packaging materials. A wide range of biopolymers has been explored for use in packaging (ULLAH; AHMED, 2025). Currently, it is observed that the food packaging industry uses synthetic polymers as raw materials due to their low cost, accessibility, flexibility, and lightness. Therefore, the production, study, and application of biodegradable polymer compounds are essential to address current sustainability challenges (EDO *et al.* 2025).

2.2. Types of biopolymers

Over time, the industrial sector has shown a growing interest in biopolymers, making them an alternative to conventional petroleum-derived polymers due to their biodegradation rate, lower environmental impact, and independence from non-renewable resources. The need for new materials of biopolymer origin is expected to grow significantly, assuming increasing proportions due to demand and market changes (EDO *et al.* 2025). With scientific development, it has become possible to produce various sustainable polymers to meet different application areas, such as...

food packaging sector. Many of them are variations of, or are developed from, existing molecules, such as cellulose obtained from vegetable fibers (SANTOS, 2021).

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Besides cellulose, there are several biopolymers whose applications vary significantly from one another. Among the most commonly used are starch, polylactic acid, chitosan, and proteins. These biopolymers are widely used in the production of bags, flexible packaging, and packaging films in the food industry. These materials are produced from different sources and are susceptible to various challenges, such as low mechanical strength, sensitivity to moisture, and limited processability due to the requirements for controlling process variables like temperature. The industry requires further innovation to improve the mechanical strength and moisture affinity of biopolymers (BABAREMU; OLADIJO; AKINLABI, 2023).

Proteins are natural biopolymers composed of amino acids linked by peptide bonds; examples include silk, collagen, and keratin. They exhibit a variety of biological functions and are employed in the production of food, pharmaceuticals, tissue engineering, and numerous other applications. Proteins such as soy and whey proteins can be used in the manufacture of biodegradable packaging materials and are frequently employed in conjunction with other materials to improve the mechanical strength and flexibility of these materials (ULLAH; AHMED, 2025).

Besides proteins, other biopolymers stand out, such as polylactic acid (PLA) and polyglycolic acid (PGA), produced from recyclable materials like sugarcane or corn starch, and PLA, frequently used in the production of packaging components and biodegradable polymers. PLA and PGA can be produced from biomass, petrochemical products, and polycaprolactone, as well as butylene succinate-co-adipate. Separately, PLA is one of the most widely used biopolymers in packaging. It is biodegradable and compostable under certain conditions, making it suitable for single-use and short-term packaging applications, including cups, containers, and films (ULLAH; AHMED, 2025).

Starch is frequently used as a component of biodegradable packaging materials. These packages are suitable for items such as disposable cutlery, bags, and food containers. Cellulose is obtained from renewable sources such as wood pulp and cotton, and cellulose films and coatings offer good barrier properties in bio-based packaging materials such as labels and transparent windows. Chitosan is derived from chitin, an organic polymer found in the outermost layer of crustaceans such as shrimp and crab. Chitosan-based films and coatings can be used in packaging, especially in the food industry, to impart properties...

Antibacterial properties and extend the shelf life of products. Poly(hydroxyurethanes), on the other hand, are produced from renewable resources and used in biomedical applications, such as drug delivery and tissue engineering. They are also used in flexible and rigid packaging and can be used as sustainable alternatives to traditional plastics.
Peptoids are bio-inspired synthetic polymers that mimic the structure of peptides but are more resistant to enzymatic degradation. They have potential applications in drug delivery and materials science. Meanwhile, nucleic acids, such as DNA and RNA, are biopolymers composed of nucleotide units and are essential for the storage and transfer of genetic information in living organisms (ULLAH; AHMED, 2025).

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2.3. Application in packaging

According to Stoica *et al.* (2024), packaging plays a crucial role in protecting food from physical damage and external microorganisms. Polymers derived from fossil fuels are widely used in the food industry as packaging materials due to their advantageous properties, such as transparency, aesthetic appeal, good barrier and mechanical properties, versatility, combinability, processability, and cost-effectiveness. Similarly, Edo *et al.* (2024) state that food packaging, for example, is essential to protect food against

Protect from external contamination and maintain its quality, safety, and purity throughout its shelf life. The food industry primarily uses synthetic polymer-based materials for packaging due to their low cost, ease of manufacture, accessibility, flexibility, and lightness. Furthermore, the development and application of biodegradable polymer compounds are necessary to address environmental challenges and keep pace with sustainable development, which is gaining traction in the industrial sector.

Therefore, the excessive use of polymer-based packaging, still dominant in the food packaging sector, represents a serious problem for ecological sustainability, as projections indicate that, by 2050, plastic waste could outnumber marine life in ocean environments. Since the nature of conventional polymers is non-renewable, the longevity of these materials and the expectation of almost tripling global consumption contribute significantly to the worsening of environmental crises, mainly due to the exorbitant quantity produced daily worldwide (RAJENDRAN *et al.* 2024).

In recent years, packaging *design* has shifted its focus from conventional passive packaging to eco-friendly active packaging, which meets consumer demands for healthier and safer foods. This is because the market is increasingly pressured to demand sustainable products as a way for industries to address environmental concerns, as this will affect their profitability, rather than simply providing protection against the external environment, as conventional passive packaging does. In this context, natural biodegradable biopolymers, due to their unique physicochemical properties, represent a promising alternative to fossil-based polymers, offering a sustainable solution for eco-friendly active packaging (STOICA *et al.* 2024).

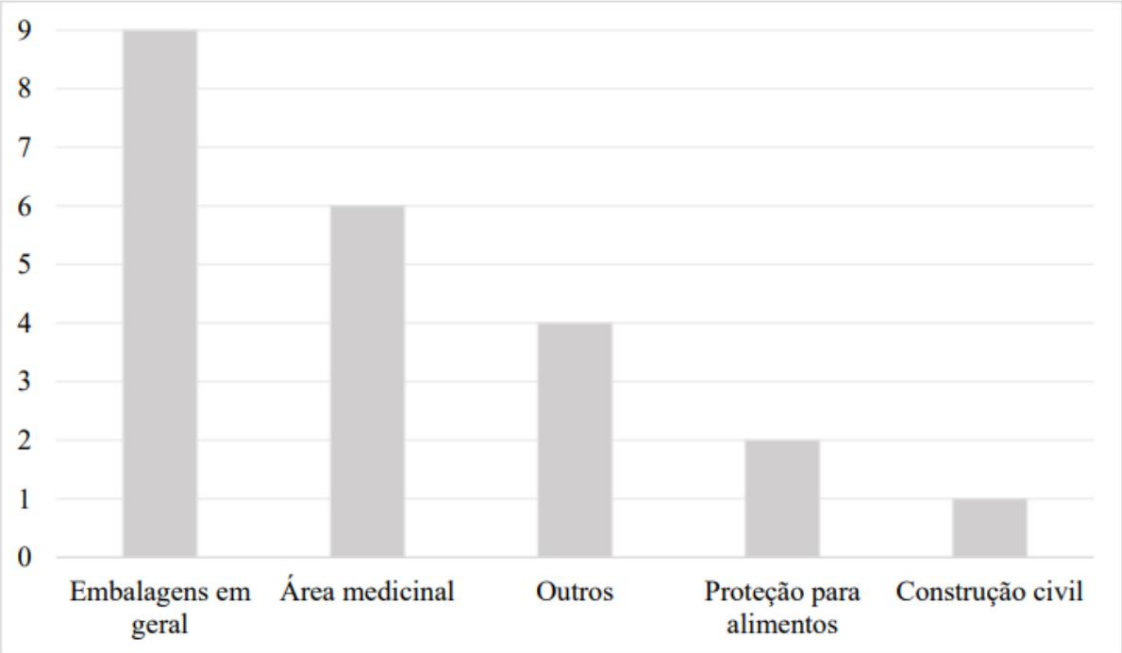
The packaging production sector is one of the largest generators of waste; therefore, several studies point to the applications of biodegradable materials. Figure 1 demonstrates the main areas of application of biopolymers identified by Santos (2021): Bio-PE (Green Polyethylene), Bio-PET (Renewable Poly(ethylene terephthalate)), Bio-PTT (Poly(trimethylene terephthalate)), PLA (Polylactic Acid), PHA (Polyhydroxyalkanoates), starch, PBAT (Poly(butylene adipate-co-teregphthalate)), PCL (Poly(caprocalctone)), and PBS (Poly(butylene succinate)).

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Figure 1 – Types of biopolymers X main areas of application



Source: Santos (2021).

From Figure 1, it can be analyzed, along with the thinking of the authors Ullah and Ahmed (2025), that, because they are biodegradable plastics, they have an extremely wide range of applications; they also highlight their popularity due to their effectiveness in packaging cosmetics and personal hygiene items, as well as food, because PHA films and coatings provide barrier properties that protect the packaged products.

According to Pinto (2022), there are different applications of biopolymer compounds. In this context of degradation, the three main mechanisms should be observed, described as: physical, chemical, and caused by microorganisms, as well as the main performance attributes applicable in packaging or improvement of existing ones. These include the toxicity of the constituent materials of the film, barrier properties, mechanical properties (elongation, adaptability to product dimensions, and flexibility), and chemical stability in relation to the permeability of water, oil, gases, and solvents, which can compromise safety and quality in the food packaging segment.

2.4. Technical and economic aspects

Fogaça and Irazusta (2021) demonstrated that there is currently great interest in research and development of technologies for the synthesis and production of polymers based on natural resources (biopolymers), due to their high degradability without generating toxic waste, and highlighted that industries have been seeking materials whose deposition does not harm the environment and are low-cost. Jin and Spontak (2023) state that scaling up production can improve manufacturing capabilities, reduce product costs, and ultimately promote the adoption of materials in current and developing markets.

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In technical terms, unfortunately, these biopolymers have some disadvantages, such as extreme vulnerability to water and inferior mechanical and thermal barrier properties.
Stoica *et al.* (2024) suggest mixing them with other materials to design more effective food packaging. Furthermore, the incorporation of antimicrobials and antioxidants can enhance the functionality of these films, contributing to the successful application of biodegradable biopolymers in engineered food packaging and helping to mitigate the environmental crises associated with the widespread use of conventional polymer packaging.
Despite numerous attempts to inspire a world of environmentally friendly and sustainable materials for the future of society and the planet, the necessary changes in industry remain a major obstacle. The global dependence on synthetic polymers derived from limited fossil resources can be reduced by replacing them with bio-based materials. Furthermore, a separate, but no less significant, advantage of bio-based materials derived from food waste is the reuse of food scraps and residues from their industrial processes, making the food industry more sustainable, increasing compostable and biodegradable materials, and consequently reducing the accumulation of solid waste and the production of nano/microplastics.

(JIN; SPONTAK, 2023).
It is expected that the technical substitution potential of biopolymers in relation to conventional synthetic plastics, as well as the substitution rate, will reach values of up to 90%. Therefore, this demonstrates that biopolymers have the potential to eventually, with technological advancements and discussion on the subject, replace most conventional polymers currently used in everyday life. As the increasing commercialization of biopolymers results in lower costs and improved technological capabilities, this number may begin to seem more attainable, although it is still a long way off (SANTOS, 2021).

2.5. Environmental aspects

With the industrial revolution, numerous technological advances emerged, with a wide spectrum of global benefits; however, these advances proved to be a double-edged sword, since numerous discoveries positively affect humanity but equally harm the environment (JIN; SPONTAK, 2023).
Marcheze *et al.* (2024) highlight the growing environmental importance. The use of biopolymers emerges as an alternative to minimize the environmental impacts caused by polymers, due to the generation of waste that is difficult to degrade.
Jin and Spontak (2023) highlight that a large part of the projects focused on sustainable and ecological materials currently concentrate on innovative strategies to reduce global environmental damage and establish environmentally friendly standards for the future. To achieve this goal and reduce the current dependence on conventional polymers, chemical and process advances must be promoted for the adoption and adaptation of natural resources.
In this way, sustainability is a much-discussed concept today, based on the principle of the *triple bottom line* (the three pillars of sustainability), with financial results, social responsibility, and environmental preservation as its central ideas. Production systems must take these three pillars of sustainability into account, known as...

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People- profit-planet. With this in mind, the concern for renewable packaging and biopolymers has become a relevant topic today, as they can replace synthetic plastics that are difficult to degrade. Biopolymers, although still more expensive, are a sustainable alternative to replace polymers derived from non-renewable sources, as they have a shorter degradation time in the environment and offer multiple applications (FOGAÇA; IRAZUSTA, 2021).

In summary, biopolymers demonstrate high potential as sustainable alternatives to petroleum-based polymers, reducing the effects of greenhouse gases on the environment.
Plastic packaging made from biodegradable polymers is rapidly taking the lead in social responsibility and in promoting a sustainable and healthy lifestyle.
It also includes properties such as biodegradability and biocompatibility, which demonstrate a range of benefits and increase the likelihood of its use in various fields.
In addition to the packaging sector, the materials used in the production of biopolymers have been examined by scientists and engineers to assess their effectiveness, safety, and environmental impact (EDO *et al.* 2025).

3. Method applied

Scientific research is a structured and rational procedure that aims to identify answers to proposed problems on a given topic, playing an important role in the advancement of knowledge and contributing to academic, technological, and social development. Scientific study can be carried out through a methodological classification involving four main criteria. Regarding purpose, research can be exploratory, descriptive, or...

explanatory, according to the objective of the investigation (GIL, 2008).
Regarding the nature of the research, it can be basic, when it seeks to expand knowledge, or applied, when its objective is to solve specific problems (PRODANOV; FREITAS, 2013).

Regarding the approach, research can be qualitative, prioritizing the interpretation of phenomena, or quantitative, which uses numerical data and statistical techniques for analysis (PRODANOV; FREITAS, 2013). As for the method, it refers to the procedure adopted to carry out the investigation, which may be RBS (Systematic Literature Review), case studies, surveys, experimental research, among others (GIL, 2008).

3.1. Characterization of the research

This study is characterized as a Systematic Literature Review (SLR), a method used to identify, select, analyze, and synthesize scientific evidence on a specific topic (GALVÃO; PEREIRA, 2014). According to Conforto, Amaral, and Silva (2011), SLR allows for the structured and rigorous gathering and evaluation of relevant information available in the literature. Thus, this method was adopted to assess the feasibility of replacing conventional polymers with renewable materials in the food packaging sector.

The research adopted a qualitative approach, seeking to interpret and compare the results of the selected studies based on their technical, environmental, and economic aspects.

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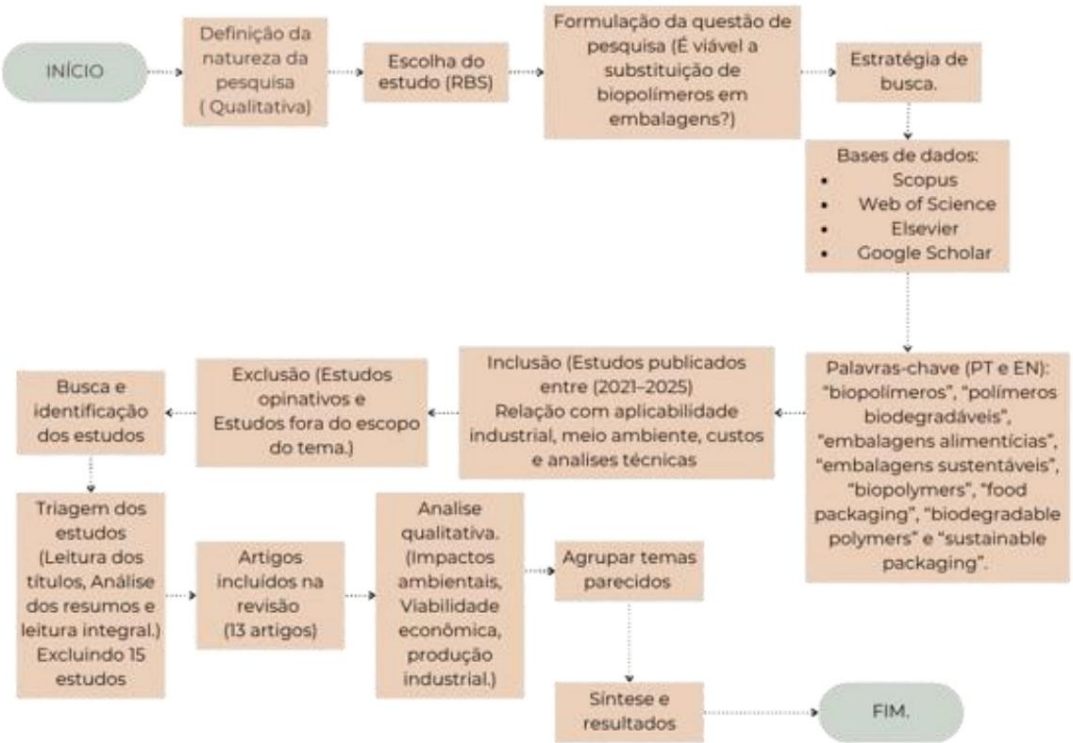
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biopolymers. According to Botelho, Cunha and Macedo (2011), a systematic literature review follows a clear and reproducible method, ensuring scientific rigor and the possibility of replicating the procedures. This study is characterized as exploratory and descriptive, of a pure nature, with a qualitative approach, developed through a systematic literature review, whose objective was to gather and analyze recent scientific publications related to the use of biopolymers in food packaging, identifying advantages, limitations and challenges for the replacement of conventional polymers of fossil origin.

The production steps for this systematic literature review occurred sequentially, as shown in Figure 2 below.

Figure 2: Flowchart of the methodological process.



Source: Prepared by the author (2026)

3.1.1. Database Definition

Bibliographic searches were conducted in the Scopus, Web of Science, Elsevier, and Google Scholar databases. These databases were chosen due to their broad scope of scientific publications in the areas of engineering, materials, sustainability, and food packaging.
According to Biolchini *et al.* (2005), defining the databases is part of the methodological process of systematic literature review, being fundamental to guaranteeing the reliability and traceability of the research; thus, it was decided to use databases recognized internationally for their relevance and the quantity of indexed publications. The searches for

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The articles were limited to publications between 2021 and 2025, aiming to select recent studies and ensure alignment with technological advances related to biopolymers and sustainable packaging.

3.1.2. Definition of keywords

To conduct the searches, keywords related to the research topic were used. The searches were performed using words in both Portuguese and English, with the aim of broadening the scope of the results. Among the main terms used, the following stand out: "biopolymers", "biodegradable polymers", "food packaging", "sustainable packaging", *"biopolymers", "food packaging", "biodegradable polymers"* , and *"sustainable packaging".* The definition of the keywords was based on the research objective and a prior analysis of the literature; according to Conforto, Amaral and Silva (2011), the selection of keywords for the search is very important to ensure the quality and relevance of the studies found in a biographical database. The keywords were combined using Boolean operators, such as "and" and "or", allowing the results to be refined for better alignment with the topic of replacing conventional polymers with biopolymers in the food packaging sector.

3.1.3. Criteria for including articles

In this stage, complete scientific articles published between 2021 and 2025 related to the use of biopolymers in food packaging were included, as well as research involving technical, environmental, or economic analyses, in addition to works fully available in the selected databases, totaling 28 studies. Fifteen articles were excluded, including duplicates, studies not directly related to the proposed theme, publications without access to the full text, and studies without relevant results on the topic. According to Botelho, Cunha, and Macedo (2011), the inclusion and exclusion criteria for publications ensure methodological rigor. After defining the criteria, 13 scientific articles were selected to compose the qualitative analysis of the research.

3.1.4. Data Analysis

The data analysis was conducted qualitatively, through a complete reading and critical interpretation of the selected studies; thus, information related to the properties of biopolymers, biodegradability, mechanical resistance, thermal stability, moisture sensitivity, production costs, industrial applications, and environmental impacts was analyzed. Botelho, Cunha, and Macedo (2011) state that systematic literature review allows for the organization and synthesis of existing scientific knowledge, contributing to the identification of gaps and research trends. Therefore, the data obtained allowed for a comparison of the main biopolymers used in food packaging, such as PLA (polylactic acid), starch, cellulose, and chitosan, as well as the identification of the technical and economic challenges to their large-scale industrial application. The results were organized and discussed in light of recent scientific literature, allowing for an assessment of the viability of the field.

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to replace conventional polymers with sustainable polymers in the food packaging sector.

4. Results and discussion

This systematic literature review allowed us to analyze the feasibility of replacing conventional polymers, derived from non-renewable raw materials, with biopolymers in the food packaging segment, considering essential factors such as technical, economic, and environmental aspects. Thus, 13 articles that met the methodological criteria were analyzed, as presented in Table 1.

Table 1: Selected Studies

Author(s)	**Year of publication**	**Title of the article/work**
Fogaça, Leandro Soares Fernandes; Irazusta, Silvia Pierre	2021	*Synthesis, Applications and Degradation of Biopolymers: Literature Review*
Santos, Lucas Leite dos	2021	*Production Methods Biopolymers from Raw Materials Vegetables: A Literature Review*
Satie, Juliana; Carvalho, Becker de; Roeder, Luana Alessandra	2021	*Bioeconomy in the Amazon Biome*
Tamburini, E.; Back.; Summa, D.; Battistella, L.; Fano, EA; Castaldelli, G.	2021	*Plastic (PET) vs Bioplastic (PLA) or Refillable Aluminum Bottles—What Is the Most Sustainable Choice for Drinking Water? The Life-Cycle (LCA) Analysis*
Pinto, Milena Patrícia Martinez de Almeida	2022	*Analysis of the Technological Feasibility of Obtaining Biopolymers from Açaí for Application in Packaging*
Rosenboom, J.G.; Langer, R.; Traverso, G.	2022	*Bioplastics for a Circular Economy*
Babaremu, Kunle; Oladijo, Oluseyi P.; Akinlabi, Esther	2023	*Biopolymers: THE Suitable Replacement for Plastics in Product Packaging*
Jin, Soo-Ah; Spontak, Richard J.	2023	*Fundamentals of and Advances in Nanocellulose and Nanochitin Systems*
Marcheze, Gabriel Gonçalves et al.	2024	*Study of biopolymers as a sustainable alternative*
Rajendran, Devi Sri et al.	2024	*A Review on Bio-Based Polymer Polylactic Acid Potential on Sustainable Food Packaging*
Stoica, Maricica et al.	2024	*Review of Bio-Based Biodegradable Polymers: Smart Solutions for Sustainable Food Packaging*
Edo, GI; Ndudi, W.; There, ABM; Yousif, E.; Jikah, AN; Isoje, EF; Igbuku, UA; Mafe, AN; Opiti, R.	2025	*Biopolymers: An Inclusive Review*

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A.; Madueke, CJ; Essaghah, AE A.; Ahmed, DS; Umar, H.		
Ullah, Aman; Ahmed, Shakeel (ed.) 2025		*Green Biopolymers for Packaging Applications*

Source: Prepared by the author (2026)

Based on this qualitative analysis of the selected studies, it was observed that biopolymers represent great sustainable potential and increasing industrial applicability; however, limitations related to cost, mechanical properties, and industrial scalability still exist.

4.1. Points of consensus identified in the literature

Based on the 13 studies analyzed, a link was demonstrated between the sustainability potential and the positive alternative of replacing conventional polymers with biopolymers. These studies indicate that biodegradable materials have a shorter degradation time and allow the use of renewable raw materials, resulting in less environmental impact. Babaremu, Oladijo, and Akinlabi (2023), Stoica *et al.* (2024), and Edo *et al.* (2025) highlight, in their studies, the contributions of biopolymers to the reduction of solid waste and pollution caused by conventional plastic packaging. Thus, an alignment was observed among the studies regarding the growing industrial demand for sustainable materials, driven by environmental concerns and market pressure.

4.2. Comparison between biopolymers and conventional polymers

Common polymers are still widely used in the food packaging industry due to their properties, ease of processing, and low production costs.
Stoica *et al.* (2024) state that these fossil-based materials have many advantages for packaging, such as flexibility, product protection properties, and good cost-effectiveness, which demonstrates their predominance in the food packaging segment. Edo *et al.* (2025)
They also discuss the popularity of synthetic polymers due to their ease of manufacture, affordability, and versatility of applications.
Of the 13 selected articles, there was consensus regarding the negative environmental impacts of these synthetic polymers. Rajendran *et al.* (2024) emphasize that the increased consumption of plastic packaging is directly linked to the increase in solid waste and environmental pollution, mainly due to the degradation time of these materials.
Tamburini *et al.* (2021) conducted a life cycle analysis of biodegradable materials, such as PLA, which presents environmental advantages over PET, mainly due to its production from renewable raw materials and the reduction of dependence on limited fossil compounds.

However, the authors emphasize that environmental impacts depend on the production, reuse, and disposal of products.
Biopolymers have a lower environmental impact in production and disposal, making them an alternative to conventional packaging. Babaremu Oladijo and Akinlabi (2023) state that materials such as PLA, starch, cellulose, and chitosan are promising biopolymers with great potential.

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Its application is in the biodegradable packaging sector. This is due to factors such as its renewable origin and high degree of natural degradation.
Ullah and Ahmed (2025) also highlight the application of these compounds in the production of biodegradable films and coatings for food packaging, among other sectors. Rosenboom Langer and Traverso (2022) and Pinto (2022) also emphasize the importance of biopolymer production in the circular economy, whose raw material can be composed of recovered waste, which reduces the costs of the production process.
Significant technical limitations have been identified. Stoica et al. (2024), for example, state that several biopolymers exhibit low strength, sensitivity to moisture, and low thermal stability. Babaremu, Oladijo, and Akinlabi (2023) add that these limitations currently represent a major problem for industrial-scale applications, as greater durability and strength are still required. Pinto (2022) also adds that there are several challenges to overcome, such as permeability and chemical and hydrophobic stability, so that biopolymers can replace traditional ones.

In addition to technical issues, economic limitations were pointed out. Fogaça and Irazusta (2021) discuss the factor that the production costs of biopolymers are currently much higher than those of conventional polymers, making their insertion into the packaging market more difficult. However, Jin and Spontak (2023) argue that technological advancements and increased production can help reduce costs and improve the performance of these materials in the future. Thus, although biopolymers demonstrate their environmental importance, there is still a need for technological advances, improvements in material properties, and economic viability.

4.3. Discrepancies in the literature and observed limitations

According to the articles analyzed, a great potential for the sustainable replacement of conventional polymers with biodegradable materials was perceived. However, there are disagreements as to whether this replacement can actually occur in the packaging area, as some authors have an optimistic view, saying that it is possible but requires technological advances, growth, and market acceptance. Santos (2021) states that the factor of technological evolution, process improvement, and improvement in the properties of these biodegradable materials will allow the replacement of conventional polymers, in the same line of thought. Jin and Spontak (2023) say that increasing the scale of production can help reduce costs and facilitate acceptance and investment in this sustainable sector, but some authors mention the technical limitations that make large-scale production difficult, as Stoica *et al.* (2024) state that biopolymers are restricted for packaging that needs high performance due to factors such as strength, moisture sensitivity and thermal limitations, Babaremu, Oladijo and Akinlabi (2023) complement this with the thought that technological development will help to overcome these challenges related to the production process and mechanical characteristics of the products.

Economic viability is another aspect on which the literature diverges considerably. Fogaça and Irazusta (2021) state that, although biopolymers are advantageous for the environment, production costs are high, especially compared to polymers of ecological origin.

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fossil. Rosenboom, Langer and Traverso (2022) state that the increased demand for sustainable materials and the circular economy are leading investors to take an interest in this segment.
making biopolymers more competitive in the future.
Another limitation observed was the biodegradability of these materials under different environmental conditions. Thus, Pinto (2022) adds that physical, chemical, and microbiological aspects can interfere with the performance of biodegradable products. This demonstrates that the degradation of biopolymers does not occur uniformly under different conditions of use and disposal.
Thus, it is clear that the authors agree on the environmental benefits of biopolymers, but there is still disagreement regarding limiting factors such as technical performance, economic viability, and the capacity for large-scale production. These factors highlight the need for further research focused on technological development and process improvement to enable large-scale production.

Conclusion

Of the 13 selected articles, some relevant gaps were revealed regarding how biopolymers can be used in the food packaging industry; most studies focus on the environmental benefits and general characteristics of biodegradable materials, but research addressing large-scale production and a complete economic analysis of the process is still lacking. Jin and Spontak (2023) state that this increase in production still requires technological advances and reductions in process costs, these being essential factors for introducing biopolymers to the market. Furthermore, Stoica *et al.* (2024) comment that there are few studies evaluating the performance of biopolymers in real-world situations of food storage, transport, and preservation. In addition, Pinto (2022) highlights the importance of in-depth studies on permeability, chemical stability, mechanical resistance, and interaction between biodegradable packaging and various types of food.

Another gap observed was the technical limitations of biopolymers. Babaremu, Oladijo, and Akinlabi (2023) point out that problems such as sensitivity to moisture, lower mechanical strength, and thermal restrictions hinder the use of biodegradable materials in food packaging. Rajendran *et al.* (2024) highlight the need for technologically advanced materials to improve the competitiveness of these materials in relation to traditional polymers.

Thus, the results obtained demonstrated that biopolymers may soon partially replace polymers of non-renewable origin, as cited by Jin and Spontak (2023). New technologies are needed to mitigate costs and improve the properties of food packaging, highlighting Pinto's (2022) idea of innovations such as hybrid materials and process improvements. These strategies are necessary for the viable application of renewable polymers in the food packaging sector. However, we realize that currently, large-scale production to replace conventional polymers is unfeasible due to technical and economic limitations.

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