

Chapter: 16

BIODEGRADABLE PACKAGING: FOCUS ON STARCH-BASED ALTERNATE FILMS

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ABSTRACT

Starch-based biodegradable packaging has emerged as a promising and sustainable alternative to conventional packaging materials. This review delves into the key aspects of starch-based biodegradable packaging, exploring its significance in the context of environmental concerns and the growing demand for eco-friendly alternatives. The review covers the materials involved, their characteristics, and the environmental implications of adopting starch-based biodegradable packaging. The exploration of starch-based materials opens new avenues for environmentally conscious packaging solutions.

Keywords: *Packaging, Biodegradable, Starch, Biopolymer.*

1. INTRODUCTION

The escalating environmental challenges posed by non-biodegradable packaging materials have intensified the quest for sustainable alternatives. Starch-based biodegradable packaging has garnered attention for its potential to mitigate the environmental impact associated with traditional packaging [1-4]. This section introduces the rationale behind the shift towards starch-based alternatives, emphasizing the need for eco-friendly materials in the packaging industry. The review also outlines the objectives of exploring starch-based biodegradable packaging, considering both its ecological benefits and industrial applications. This segment delves into the diverse range of materials employed in starch-based biodegradable packaging [5]. Starch, a renewable and abundant resource, serves as the primary component. The review examines the processing techniques involved in transforming starch into viable packaging materials, exploring the integration of additives to enhance performance and biodegradability. Additionally, the section discusses the mechanical, thermal, and barrier properties of starch-based packaging materials, providing insights into their feasibility for various applications.

2. STRUCTURAL AND FUNCTIONAL ATTRIBUTES

Starch's membrane- and gel-forming characteristics arise from its linear structure, fostering hydrogen bonds between hydroxyl groups of parallel-oriented chains. Notably, the presence of higher amylose content in edible films enhances their film-forming properties, including superior mechanical strength, elongation, and gas barrier capabilities. These attributes position starch-based films as a promising option for the production of edible films and coatings, leveraging their inherent tasteless, odorless, colorless, and non-toxic nature. Despite their advantageous properties, the mechanical integrity of these films is affected by their high water vapor permeability. Starch, scientifically known as amyllum, constitutes a polymeric carbohydrate

characterized by the linkage of numerous glucose units through glycosidic bonds. This complex polysaccharide serves as a primary energy storage mechanism in most green plants, making it a ubiquitous component in human diets worldwide. Abundantly present in staple foods like wheat, potatoes, maize (corn), rice, and cassava (manioc), starch plays a fundamental role in providing energy and sustenance.

In its pure form, starch manifests as a white, tasteless, and odorless powder, exhibiting insolubility in cold water or alcohol. Its structural composition involves two distinct molecules: amylose, which is linear and helical, and amylopectin, characterized by branching. The typical composition of starch varies, with approximately 20 to 25% being amylose and 75 to 80% amylopectin by weight [7]. Notably, glycogen, serving as the energy reserve in animals, represents a more intricately branched version of amylopectin. In industrial settings, starch often undergoes conversion into sugars, a process exemplified by malting. These sugars, in turn, may undergo fermentation to yield ethanol, contributing to the production of beverages like beer and whisky, as well as biofuels. Furthermore, sugars derived from processed starch find application in a myriad of processed foods, illustrating the versatile role of starch in various industrial processes. Beyond its culinary applications, starch finds extensive use in non-food industrial sectors. When mixed with warm water, most starches form a paste, such as wheat-paste, serving as a valuable thickening, stiffening, or glueing agent. The industrial realm particularly benefits from starch's adhesive properties, employing it in the papermaking process. An analogous application involves clothing starch, which can be applied to specific textile goods before ironing, enhancing their stiffness and appearance.

Starch, a cost-effective carbohydrate-based polymer derived from a variety of crops, plays a pivotal role in the development of biodegradable packaging. The native starch granules, comprising a combination of amylopectin (75%) and amylose (25%), form a distinctive structure with inherent properties crucial for packaging applications [6]. Amylose, characterized by linear molecules connected through α -1,4 bonds, contrasts with the highly branched amylopectin, which integrates both α -1,4 and α -1,6 bonds (Figure 1). Widely distributed in plants such as tubers, seeds, and roots, starch from industrial sources like maize, wheat, edible cassava, potato, amaranth, and quinoa offers versatility in its applications [7-10].

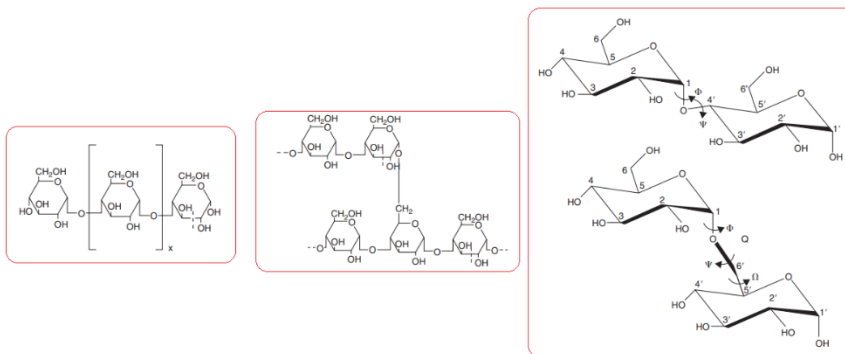


Figure 1: (i) Amylose; and (ii) Amylopectin branched at O₆, (iii) Schematic components of starch: maltose [α Glc-(1 \rightarrow 4)Glc] and isomaltose [α Glc(1 \rightarrow 6)Glc].

However, the multifaceted nature of starch extends beyond its role as a dietary staple, encompassing significant contributions to both industrial processes and non-food applications, making it a compound of paramount importance in various domains. Starch-based films demonstrate commendable barrier properties against gases, illustrating their potential for applications in the packaging industry. Their cohesive strength and durability further underscore their suitability for a wide range of products. The accessibility of starch from diverse sources ensures its widespread applicability, offering a sustainable and eco-friendly solution for the development of packaging materials. As the demand for environmentally conscious practices grows, the industrial significance of starch-based biodegradable packaging materials becomes increasingly apparent.

3. SUSTAINABLE ASPECTS

Sustainability is commonly classified into three pivotal dimensions—human well-being, the economy, and the environment [11]. These dimensions serve as integral components for enhancing human welfare, ensuring fair burden-sharing, and social equity, and upholding ecosystem resilience [12]. From an ecological standpoint, fostering sustainability necessitates active contributions to maintaining a healthy environment and ecosystem. This perspective extends to the realm of packaging materials, where sustainability is achieved through the reduction of virgin resource consumption and the recyclability or reusability of post-consumer materials from readily available resources [13]. Material sustainability involves a complex interplay of various factors, encompassing economic and environmental considerations. Factors such as costs, impacts, functional and aesthetic properties, as well as the entire lifecycle—from production to end-of-life processing—contribute to the sustainability of materials.

This evaluation extends across local and global scales, recognizing the interconnectedness of environmental impacts. While some authors acknowledge that achieving absolute sustainability is a formidable challenge, if not an almost insurmountable one, it underscores the intricate balance required in navigating the multifaceted landscape of sustainable practices.

In the context of biopolymers, such as starch-based materials, the pursuit of sustainability takes on a particularly crucial role. Biopolymers derived from renewable resources, like starch, present an opportunity to address the challenges posed by traditional packaging materials. By reducing reliance on non-renewable resources and incorporating materials that are recyclable or biodegradable, starch-based biopolymers contribute significantly to the broader objectives of sustainable packaging [14]. This shift not only aligns with environmental considerations but also fosters a more circular and responsible approach to material use, supporting the overarching goal of achieving a sustainable and resilient future.

4. CHALLENGES AND FUTURE DIRECTIONS

While starch-based films exhibit promise, challenges persist, particularly concerning compromised mechanical properties due to high water vapour permeability. Addressing this issue requires innovative approaches in material engineering and processing techniques. Future research should focus on refining the mechanical attributes of starch-based films to enhance their overall performance, making them a competitive and sustainable alternative in the evolving landscape of biodegradable packaging [4,15]. Through continuous innovation and scientific exploration, starch-based biodegradable packaging materials hold the potential to revolutionize the packaging industry by providing eco-friendly alternatives with enhanced structural integrity and functional capabilities.

5. CONCLUSION

Starch-based biodegradable packaging materials exhibit immense potential in addressing the environmental challenges associated with traditional packaging. The review concludes by summarizing the key findings and implications of adopting starch-based alternatives in the packaging industry. While highlighting the environmental advantages, the conclusion also addresses potential challenges and areas for future research. The transformative role of starch-based biodegradable packaging in promoting sustainability underscores its significance as a viable and eco-friendly solution for the evolving needs of the packaging sector.

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