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An review study on Natural Plant Gums as Eco-Friendly Plastic Substitutes in the Packaging Industry

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ABSTRACT

The need for sustainable packaging materials has grown due to the growing environmental issues surrounding plastic waste. Natural plant gums are a possible substitute for petroleum-based plastics since they are non-toxic, renewable, biodegradable polysaccharides with superior film-forming and barrier qualities. The main plant gums—guar gum, gum arabic, tragacanth gum, karaya gum, and locust bean gum—as well as their sources, characteristics, and packaging uses are highlighted in this article. Recent developments in gum-based biodegradable films, their benefits, present drawbacks, and potential for environmentally friendly packaging in the future are also covered. All things considered, the development of sustainable packaging systems and the advancement of a circular bioeconomy can be greatly aided by natural plant gums.

KEYWORDS
Guar gum, gum arabic, biodegradable films, renewable materials, biodegradable packaging, sustainable packaging, biopolymers, eco-friendly plastics, and circular bioeconomy.

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1. Introduction

Over the past few decades, the production and consumption of petroleum-based plastics have greatly expanded due to the extraordinary expansion of the worldwide packaging sector. Synthetic plastics like polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polystyrene (PS), and

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polyvinyl chloride (PVC) have become essential materials in food, pharmaceutical, agricultural, cosmetic, and industrial packaging applications due to their exceptional mechanical strength, flexibility, durability, lightweight nature, and low production cost. However, the widespread use of these non-biodegradable materials has had detrimental effects on the environment, such as the buildup of plastic garbage in marine and terrestrial ecosystems, greenhouse gas emissions, and the depletion of fossil fuel supplies and the development of persistent microplastics that endanger human health and biodiversity (Geyer et al., 2017; Jambeck et al., 2015; Ritchie & Roser, 2018; Sharma et al., 2021; UNEP, 2023; OECD, 2022; Siracusa et al., 2020; Ncube et al., 2020). These worries have sped up the shift to environmentally friendly, biodegradable, and renewable packaging materials that can support the circular bioeconomy's tenets and replace traditional plastics made from petroleum (European Commission, 2020; Nanda et al., 2022; Dufresne, 2021).

Because of their renewable origin, biodegradability, biocompatibility, non-toxicity, and exceptional film-forming ability, plant gums have emerged as highly promising materials for the development of environmentally friendly packaging systems among the various classes of natural biopolymers (Thakur et al., 2021; Debeaufort et al., 2022; Ahmed et al., 2022; Al-Hashimi et al., 2023). Plant gums are naturally occurring high-molecular-weight polysaccharides that are either stored in the seeds, bark, stems, and fruits of many different plant species or produced as exudates. Monosaccharides like arabinose, galactose, mannose, xylose, rhamnose, glucose, and glucuronic acid are their main structural constituents and give them exceptional rheological, emulsifying, stabilizing, and adhesive qualities (Phillips & Williams, 2018; Prajapati et al., 2019; Imeson, 2019; BeMiller, 2019).

The remarkable capacity of plant gums to generate translucent, flexible, biodegradable films and edible coatings with desired mechanical and barrier properties is partly responsible for the growing scientific interest in these materials. According to Sothornvit (2020), Rhim et al. (2021), Alizadeh-Sani et al. (2020), Roy & Rhim (2021), and many other natural and synthetic biopolymers, these polysaccharides are excellent candidates for sustainable packaging technologies because of their high viscosity, excellent water-binding capacity, and good oxygen barrier performance. Additionally, natural antimicrobial agents, probiotics, antioxidants, essential oils, and bioactive compounds can be effectively transported by gum-based films, improving food preservation, increasing shelf life, and decreasing microbial spoilage (Lv et al., 2020; Hassoun & Emir Çoban, 2022; Sharma et al., 2022).

By enhancing the physicochemical and functional characteristics of plant gums, recent developments in polymer science, nanotechnology, and green chemistry have further increased their potential uses. In addition to adding nanocellulose, cellulose nanocrystals, nano-clays, graphene oxide, metal oxide nanoparticles, essential oils, and plant extracts, researchers have successfully improved gum-based packaging materials by blending polymers with starch, cellulose, chitosan, gelatin, alginate, and proteins (Dufresne, 2021; Ahmed et al., 2022; Nanda et al., 2022; Al-Hashimi et al., 2023; Ramesh et al., 2024). By greatly enhancing tensile strength, elasticity, thermal stability, water resistance, antibacterial activity, antioxidant capacity, and gas barrier qualities, these alterations overcome many of the intrinsic drawbacks of natural polysaccharide films.

The widespread industrial commercialization of plant gum-based packaging materials is nevertheless constrained by a number of issues, despite their outstanding benefits. When compared to synthetic plastics, the majority of plant gum films have poorer mechanical strength, limited thermal stability, weak water vapor barrier qualities, and comparatively high moisture sensitivity. Furthermore, product consistency and large-scale manufacturing may be impacted by variations in gum composition brought on by botanical origin, extraction methods, storage conditions, and environmental factors (Debeaufort et al., 2022; Ahmed et al., 2022; Al-Hashimi et al., 2023). In order to increase the industrial usability of these materials, future research should concentrate on creating multifunctional nanocomposites, eco-friendly cross-linking techniques, scalable processing technologies, and economical production methods.

All things considered, natural plant gums are a potential class of sustainable biopolymers that could take the place of petroleum-based plastics in a variety of packaging applications. They are desirable options for next-generation sustainable packaging systems due to their abundance, biodegradability, superior film-forming qualities, and compatibility with new green technologies. Thus, the sources, chemical makeup, physicochemical characteristics, extraction methods, film-forming mechanisms, recent technological developments, packaging applications, environmental advantages, present difficulties, and potential future developments of natural plant gums as environmentally friendly plastic alternatives in the packaging sector are all thoroughly covered in this review.

Conclusion

In the packaging business, natural plant gums show great promise as ecological and biodegradable substitutes for traditional petroleum-based polymers. They are ideal for food, pharmaceutical, and active packaging applications due to their superior film-forming capacity, biocompatibility, and renewable nature. The article emphasizes how their mechanical and barrier qualities can be further improved by material alterations including polymer mixing and nanocomposite reinforcement. Ongoing technological developments are anticipated to get over obstacles including moisture sensitivity and large-scale commercialization. All things considered, plant gum-based packaging is a viable strategy for creating eco-friendly packaging systems and promoting a circular bioeconomy.

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