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Editorial

Biopolymers for Food Packaging and Biomedical Applications: Options or Obligations?

Ruchir Priyadarshi [1,*], Swarup Roy [2,*], Shiv Dutt Purohit [3,*] and Tabli Ghosh [4,*]

1 Bionanocomposite Research Center, Department of Food and Nutrition, Kyung Hee University, Seoul 02447, Korea
2 School of Bioengineering and Food Technology, Shoolini University, Solan 173229, India
3 School of Chemical Engineering, Yeungnam University, 280 Daehak-ro, Gyeongsan 38541, Korea
4 Department of Food Engineering and Technology, Tezpur University, Tezpur 784028, India
* Correspondence: ruchirpriyadarshi@gmail.com (R.P.); swaruproy2013@gmail.com (S.R.); purohitshivdutt@gmail.com (S.D.P.); tablighosh1@gmail.com (T.G.)

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Citation: Priyadarshi, R.; Roy, S.; Purohit, S.D.; Ghosh, T. Biopolymers for Food Packaging and Biomedical Applications: Options or Obligations? *Coatings* **2022**, *12*, 1261. https://doi.org/10.3390/coatings12091261

Received: 22 August 2022
Accepted: 25 August 2022
Published: 29 August 2022

Since the invention of synthetic plastics in the 1950s, they have inevitably dominated all other materials such as metals, glass, wood, etc., due to their outstanding properties including their light weight, transparency, mechanical strength and flexibility, and their ability to be molded into various shapes [1,2]. However, synthetic plastics are not biodegradable and tend to accumulate in the environment. According to the recent report on municipal solid waste (MSW) generation and disposal, published by the United States Environmental Protection Agency (US-EPA) [3], the total waste generated in 2018 was 292 million tons, out of which 35 million tons was plastic. A large part of this plastic MSW came from containers and packaging categories. Additionally, the healthcare sector generates humongous amounts of plastic waste. In the USA alone, 1.7 million tons of plastic waste is produced by the biomedical and healthcare sectors annually [4]. Furthermore, only 1.5 million tons can be recycled out of the 35 million tons produced, and the rest was landfilled or dumped into oceans, which remains the only disposal method [3]. It is estimated that more than 5 trillion pieces of plastic, with a combined weight of above 250,000 tons, are floating in the oceans [5]. These numbers indicate the extent to which plastics have contaminated the environment.

Besides the pollution caused by discarded plastics, microplastics have emerged as an even more formidable environmental hazard. Microplastics are defined as small particles of plastic material, commonly considered smaller than 5 mm, that have either been manufactured purposely (primary microplastic) or that are produced from the fragmentation of all types of plastics (secondary microplastic) [5]. The plastic pollution results in the generation of secondary microplastics, which contaminate air, soil, and water bodies. These microplastic contaminants affect not only the floral and faunal biodiversity but also humans. Being in direct contact with discarded plastics, soil and water are contaminated with microplastics [6]. There have been numerous instances where the contamination of aquatic fauna and terrestrial flora, which humans consume, have been contaminated by these microplastic materials [7]. Consequently, they accumulate in the human gut and lead to physical discomforts and diseases, from minor digestive issues to colon cancer. Therefore, research on materials that can replace petrochemical-derived plastics in several application areas is crucial, the most important aspects being packaging, biomedical, and consumer utility goods.

In the past decade, researchers have focused on utilizing natural/nature-derived polymers as sustainable materials, especially in food packaging and biomedical engineering applications, which are the two paramount application areas of biopolymers. Several classes of biopolymers, including polysaccharides, proteins, lipids, and their blends, have been studied for this purpose [1]. Most biopolymers are sustainable and obtained from renewable resources or agro-industrial waste. Examples include cellulose from the lignocellulosic forest and agricultural waste; agar, alginate, carrageenan, etc., from seaweeds [8]; chitosan from crustacean shell and fish scale waste produced by the seafood industry [9]. Semi-synthetic biopolymers such as polylactic acid and microbial-derived biopolymers such as polyhydroxyalkanoates are other potential sustainable materials studies for this purpose [1]. Furthermore, all the mentioned biopolymers are biodegradable and environmentally friendly materials, which are potential candidates to combat the hazards caused by conventional plastics and replace them for versatile applications. Their utilization in food packaging solves the issue of plastic-based municipal waste accumulation, ultimately leading to reduced carbon footprints and global warming. Besides sustainability, biopolymers possess an immense potential to carry functional components and their controlled release, paving the way for the development of active packaging [10].

Additionally, the controlled-release property of biopolymers, their non-toxicity, hydrophilicity, biocompatibility, and biodegradability make them extremely important materials for biomedical applications. Furthermore, each biopolymer's unique structural and functional properties allow biomedical scientists to efficiently engineer their properties based on their end applications. The variety of functional groups interact well with biological surfaces such as cells, resulting in enhanced adhesion, and they offer drug-attachment sites, generating potential for applications in stimuli-responsive drug release. These functionalities cannot be achieved with synthetic polymers. Hence, the progress in advanced biomedical research areas such as tissue engineering and targeted drug delivery could not be realized without biopolymers [11,12].

As a result of these lucrative properties and the application potential of biopolymers, the global biopolymer market is undergoing rapid and continuous growth. According to reports, the global polymer market was worth USD 666 billion in 2018, with an expected compound annual growth rate (CAGR) of 5.1% [13]. At the same time, the global biopolymer market reached a net worth of USD 12 billion, rising rapidly in the last decade. However, it is expected to grow at a much higher CAGR of 19% from 2019 to 2025 [11,13]. Interestingly, such a steep rise is driven by their lucrative properties, market trends, and by the necessity to search for alternative resources for polymer synthesis. According to reports, humans have already exploited and exhausted 944 billion barrels of natural oil resources, which are sources of synthetic plastics. An estimated 746 billion barrels of reserves are only left for future use, which is less than 50% [11]. These statistics are alarming for a world highly dependent on these resources to meet its energy requirements. These depleting natural fuel reserves result in forced industrial investments, innovations, and inventions, all of which boost the global biopolymer market.

Nevertheless, the biopolymer industry is still facing huge setbacks concerning processing methodologies, which require extensive research and technological developments to achieve a practical and economically viable scale-up process. Still, some of the economic and widely abundant biopolymers, for instance, starch and polylactic acid, made their way into the market [14], which is a positive indication and a motivation to navigate future research in this area. Furthermore, engineering biopolymer properties by employing methods such as incorporating potential fillers for developing nanocomposites [10], formulation of blends [15], the addition of cross-linkers, and compatibilizers [16], etc., can improve their properties for high-performance applications. The current trends and recent advancements in biopolymer engineering research assert that sustainable alternatives to petroleum-based plastics will be customary in the near future.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

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