OPEN ACCESS Freely available online

ISSN: 2157-7110
Journal of Food Processing & Technology

Perspective

Biodegradable Food Packaging: Materials, Applications, and Advances in Sustainable Food Preservation

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DESCRIPTION

Biodegradable food packaging has gained increasing attention as the food industry searches for packaging systems that can protect products while reducing the accumulation of persistent waste. Conventional food packages are commonly produced from petroleum-derived plastics that can remain in the environment for long periods after disposal. The growing volume of packaging waste has encouraged researchers and food manufacturers to investigate materials obtained from renewable biological resources. Biodegradable packaging can be designed to break down through the action of microorganisms and environmental conditions, offering an alternative approach to managing packaging materials after their useful life.

Food packaging performs several functions beyond containing a product. It protects food from physical damage, moisture, oxygen, light, microorganisms, and contamination during processing, transportation, storage, and retail. Therefore, a biodegradable package must provide sufficient mechanical strength and barrier properties while maintaining food safety. Materials based on starch, cellulose, chitosan, proteins, lipids, and biodegradable polyesters have been investigated for these purposes. The properties of each material depend on its chemical structure, processing method, formulation, and interaction with the packaged food.

Starch is one of the widely studied materials for biodegradable packaging because it is renewable, relatively inexpensive, and available from crops such as corn, potato, cassava, and wheat. Starch can be processed into films and coatings by combining it with plasticizers and other components. These materials can provide useful oxygen barriers under selected conditions, although their sensitivity to moisture can limit applications. Modification of starch through blending, cross-linking, incorporation of fibers, or combination with other biopolymers can improve selected mechanical and barrier properties.

Cellulose and its derivatives provide another important group of packaging materials. Cellulose is abundant in plant biomass and can be obtained from agricultural residues and other renewable sources. Cellulose-based films may provide good mechanical strength and oxygen barrier performance under appropriate humidity conditions. Nanocellulose, including cellulose nanofibers and nanocrystals, has received considerable research attention because of its high strength and potential to improve the structure of biodegradable films. Agricultural residues can serve as potential sources of cellulose, creating opportunities for converting underused biomass into packaging materials.

Chitosan is obtained from chitin, a structural material found in the shells of crustaceans and other biological sources. It can form transparent films and has properties that have attracted interest for food packaging applications. Chitosan-based films may provide antimicrobial activity against selected microorganisms and can serve as carriers for other functional compounds. Their performance can be modified through blending with other polymers, plasticizers, plant extracts, or nanoparticles. The suitability of chitosan packaging depends on the food product, storage environment, processing conditions, and regulatory requirements.

Protein-based packaging materials are also being studied because proteins contain functional groups that can form continuous film structures. Proteins from whey, soy, gelatin, casein, and other sources have been investigated for edible and biodegradable packaging. These materials can provide useful oxygen barrier properties and may be combined with antimicrobial or antioxidant substances. However, sensitivity to moisture and variations in mechanical strength can affect their practical use. Formulation and processing methods are therefore important for improving their performance.

Biodegradable polyesters provide another route for developing food packaging materials. Polylactic acid, polyhydroxyalkanoates, and related polymers can be produced from renewable resources or through biological processes. These materials can offer improved mechanical properties and processability compared with some natural polymer films. They can be manufactured into trays, containers, films, and other packaging formats using

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Received: 15-Sep-2025, Manuscript No. JFPT-25-32836; **Editor assigned:** 17-Sep-2025, Pre QC No. JFPT-25-32836; **Reviewed:** 01-Oct-2025, QC No. JFPT-25-32836; **Revised:** 08-Oct-2025, Manuscript No. JFPT-25-32836; **Published:** 15-Oct-2025, DOI: 10.35248/2157-7110.25.16.1185

Citation: Everwyn T (2025). Biodegradable Food Packaging: Materials, Applications, and Advances in Sustainable Food Preservation. J Food Process Technol.16:1185.

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established polymer-processing techniques. Their biodegradation behavior depends on polymer structure and environmental conditions, and appropriate waste-management systems are required to obtain the intended environmental benefits.

Edible films and coatings represent a related approach in which packaging materials can be consumed together with the food or removed before consumption. They can be applied directly to fruits, vegetables, meat products, confectionery, and other foods. Edible coatings may reduce moisture transfer, gas exchange, and surface contamination. Their use can also reduce the amount of conventional packaging required for certain products. However, sensory characteristics, coating uniformity, storage stability, and consumer acceptance must be considered during product development.

In conclusion, biodegradable food packaging provides promising opportunities for reducing dependence on persistent conventional plastics while maintaining the protective functions required for food products. Starch, cellulose, chitosan, proteins, biodegradable polyesters, and composite materials offer different combinations of mechanical, barrier, antimicrobial, and functional properties. Further progress in material formulation, processing, active packaging, safety evaluation, cost reduction, and waste management can support wider application. The development of biodegradable packaging should be guided by both food protection requirements and environmental performance so that packaging innovation contributes to a more sustainable food-processing system.