



Review on Development of Biodegradable Packaging Material

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Abstract: The study highlights specific reasons for the clothing sector, such as moisture-resistant bio-coatings intended for long-distance transportation and antibacterial wraps. The incorporation of textile waste into packaging systems provides a possible route toward a circular economy that replaces the natural environment with nutrients, overcoming difficulties like high production expenses and the requirement for professional composting. Because traditional plastic packaging is not biodegradable, it contributes extremely to pollution; therefore, the identification of sustainable replacements is crucial. The development of biodegradable packaging from basic starch films to high-performance bio-nanocomposites made of renewable resources like fibers from textiles and waste from agriculture is analyzed in this review. The main goal is to increase the mechanical strength and circularity of materials for packing by considering a variety of secondary textile fibers like cotton, jute, and hemp.

Key Words: Biodegradable Packaging, Circular Economy, Textile Waste Upcycling, Bio-nanocomposites, Nanocellulose, Natural Fibers.

I. INTRODUCTION

Packaging plays an important role in the longevity, transportation, and maintenance of products packaging improvement in quality. Whatever, traditionally plastic packing contributes relevance pollution due to its non-biodegradable nature. Biodegradable packing utilizing polymers, agro- waste, and textile fibres. Films produced from renewable resources contain long-term sustainable value because they automatically decompose by microbial activity. The circular economy and expanding ecological awareness have all been driving into biodegradable packaging choices. Although compounds take years to break down, these non-biodegradable materials are a major source of landfill storage and marine pollution (Marsh & Bugusu, 2007).

The industry is at an important turning point due to increased concern for the environment and strict regulations. Biodegradable packaging made from renewable resources including natural polymers, agricultural waste, and textile fibers has been increased by the transition toward a "Circular Economy". All of these substances are separated by having the ability to decompose microbial, hence restoring the ecosystem with nutrients (Siracusa et al., 2008). The study focuses on the development and diversity of bio-based packaging materials, from highly functional nanocellulose composites to starch-based films, and how textile science is being applied to produce sustainable, efficient replacements for standard plastics.

II. EVOLUTION OF BIODEGRADABLE PACKAGING MATERIALS

Biodegradable packaging focused on starch-based films and cellulose sheets. Over time, study explains bio-nanocomposites, textile fiber and protein composites. Biodegradable polymers such as polymers such as polylactic acid (PLA) became well-known due to their compostability and thermoplastic behavior. Modern developments incorporate nanotechnology to improve barrier and mechanical properties. The evolution moved from simple "single-material" films to "multi-function composites" that can compete with plastics strength.

III. TYPES OF PACKAGING MATERIALS

3.1 Biodegradable polymers

Polyhydroxyalkanotes (PHA), Polylactic acid (PLA), and starch blends are examples of bio- polymers that are frequently utilized. They provide:

- Biodegradability
- Eco-friendly scouring
- Decreased emissions of carbon

However, in order to decompose, they need industrial composting conditions. These are "Biodegradable," they often require industrial composting facilities (temperatures above 58 °C) to break down effectively, which is a major infrastructure

challenge (Jamshidian et al., 2010).

3.2 Packaging made of Nanocellulose

Nanocellulose improves barrier function and strength. Research shows:

- Excellent oxygen membrane qualities
- Transparency
- Lightweight design (Nair et al., 2014; Hubbe et al., 2017).
- Water vapor resistance is also enhanced by microfibrillated cellulose films (Lavoine et al., 2012).

3.3 The packaging procedure made using textile fibers

A major development in material circularity is the blending of natural fibers and post-industrial textile waste into container composites. The “valuation” of secondary textile fibers, like cotton, jute and hemp, is a rapidly expanding field of research into improving the mechanical characteristics of biodegradable matrices.

In particular, compared to regular paper-based systems, jute fiber- reinforced boards and cotton-waste composites show greater tensile strength and structural integrity. By serving as reinforcing agents, these molecules increase the packaging’s carrying capability while preserving its complete biodegradability. Additionally, using hemp and recycled textile fibers immediately reduces the environmental impact of landfill development, which is consistent with the circular textile economy’s strategic goals (Satyanarayana et al., 2009; Faruk et al., 2012). The industry is capable of a closed- loop product cycle by turning low-value textile waste into high-value effective packaging (Wang, 2010).

3.3.1 Using Textiles to Pack the Other Items

In order to strengthen biodegradable matrices, the "valorization" of secondary textiles fibers, such as cotton, jute, and hemp, is a quickly growing subject.

Structural reinforcement: Jute reinforced boards and cotton waste composites have higher tensile strength than standard paper based systems. By acting as reinforcing agents, these compounds improve a package’s capacity to transport full biodegradability.

Replacement for Plastics: The industry can accomplish a closed loop cycle by converting low value, efficient packaging, such as textile fiber boards for mailing boxes or protective partitions during transportation.

Protective Foams: Recent research mycelium textile hybrids have made it possible to shock absorbent foams that can take the place of styrofoam in electronics packaging.

3.3.2 Textile and clothing specific biodegradable packaging

The clothing sector has particular needs for packaging, like moisture protection for long distance shipment and transparency for sale.

Bio based Polybags: PLA and PHA films are taking the place of conventional polyethylene bags used for clothing. These are completely biodegradable and offer the transparency required for SKU identification.

Anti microbial garment wraps: Chitosan and protein based films are frequently used in the packaging of luxury fabrics. In steamy shipping conditions, these films characteristic antimicrobial qualities stop fungus from growing on organic materials like silk or wool.

High strength, lightweight, and transparent green barriers that shield delicate textiles from oxygen and environmental damage without the use of synthetic plastics are being made using nanocellulose for luxury clothing.

3.4 Polymers Made of starch

Biodegradable packaging material was starch- based polymers were among the first materials utilized in bio-packaging due to their low cost and abundance (Mali et al., 2005).

3.5 Polymers of Chitosan and protein

Food packaging can benefit from the beneficial antibacterial properties of chitosan films (Dutta et al., 2009). Polymers made of proteins (gelatin, soy protein) are available: Consumability, characteristics of an oxygen barrier (Gomez-Estaca et al., 2014).

3.6 Packaging for Agricultural fiber

Molded packaging is made from Agricultural waste fibers like bagasse, rice husk and wheat straw. These are: Biodegradable, low price, environmentally friendly (John & Thomas, 2008; Mohanty et al., 2005).

3.7 Bio-Coatings & edible polymers

Food shelf life increased and packing waste is decreased with edible polymers derived from proteins and polysaccharides (Falguera et al., 2011)

3.8 Packaging for Mycelium and seaweed

Packaging made of mycelium (the vegetative part of a fungus) foam is particularly useful for protecting packaging”

(replacing styrofoam-a kind of expanded polystyrene used especially for making food containers) because it can be molded into thick, shock-absorbent shapes, Bioplastics made from seaweed (algae growing in the sea). They are safe for the ocean and completely bio-degradable (Jones et al., 2020; rajendran et al., 2012).

Material Type	Examples	Key Advantages	Primary Limitation	Application
Biopolymers	PLA, PHA	Low carbon footprint	Needs industrial composting	Containers and single-use cutlery
Nanocellulose	Plant - fibers	High strength & strength	High production costs	Food wrap, electronics
Textile fiber	Cotton, Jute	Upcycles industry waste	Lower mechanical strength	Mailing boxes, partitions

Table 1: Comparative Analysis

IV.CIRCULAR & SUSTAINABLE PACKAGING SYSTEMS

By making recyclables, compositing and reuse possible, biodegradable packaging increases circular economy models (Sandin and et al., 2017).

Making use of textile waste into packaging materials increases material circularity and avoids the environmental impact (Sandin & Peters , 2018).

V.BENEFITS FOR ENVIRONMENT

- a. Decreased pollution from plastics.
- b. Reduced emissions of carbon
- c. Compostability
- d. Raw materials that are renewable

In contrast with petrochemical plastics, biodegradable plastics break down due to microbial activity(Tokiwa et al., 2009).

VI.PROBLEMS AND DIFFICULTIES

The cost of producing biopolymers and nanocomposites is higher than that of plastics.Restricted Mechanical Power certain materials are not adapted to tearing or deterioration. Moisture Sensitivity cellulose and scratch quickly absorb water. The need for industrial composting to identify many materials to break down, regulated conditions are necessary insufficient knowledge, small manufacturers are in need of environmentally friendly packaging options.

VII.PROPOSED SOLUTIONS

Making use of Textile Waste Combine cotton, jute. And leftover textile to make packing boards. Research on Bio-Nanocomposite: To make it stronger, combine natural fibers and nanocellulose. Techniques for reducing expenses encourage the government to offer rewards for biodegradable packing. Coatings that prevent moisture apply PLA, chitosan, and bee’s wax to textile packaging sheets. Encourage textile institutes to work with both academic and industry for developing package prototypes.

So can include the following particular points in your proposed solutions section to meet your professors “apparel” requirement.Particular to the industries collection:

Create mechanisms to gather “cutting room floor” waste from clothing manufactures to the point that it can be instantly transformed into shipping boxes for the same clothing.

Hybrid Bio-Coatings: To give textile packaging sheets the necessary moisture resistance required for garments transported across oceans, apply bio-coating like beeswax or PLA. Smart packaging integration: Create smart biodegradable textile containers that can track humidity levels to keep the clothing in perfect condition.

Brands can observe the lifecycle of both the garment and box at the same time through the implementation of RFID or QR-based smart packaging into biodegradable textile packaging, thereby offering a completely visible sustainable supply chain.

VIII.FUTURE EXTENT

Future studies on biodegradable packaging could concentrate on:

- Ingenious biodegradable containers
- Textile polymers with antimicrobial properties
- Edible coating for textiles
- 3D fiber packing with a mold
- Composites made of mycelium and textiles

Progress is going to be provided from the pairing of the polymer sector along with textile science.

IX. CONCLUSION

The availability of biodegradable packaging is a key component of the shift to an eco-friendly material culture, which is now required rather than optional. This review has shown that using textile fibers, agricultural waste and excellent performance. Bio-Nano composites significantly improves the ethical and practical future possibilities of packaging solutions. The industry may transition to a truly circular economy by utilizing textile technology, particularly the upcycling of waste cotton, jute and hemp. This dual-action strategy tackles the unique logistical issues of the clothing industry, such as moisture protection and antibacterial stability during transportation over long distances, in addition to providing a sustainable home for international goods.

Although there are still various challenges to overcome, especially in terms of production scalability, mechanical durability, and the economic viability of biopolymers in contrast to petroleum based plastics, changes in technology in Nano cellulose and mycelium hybrids present a promising path further. In the end, biodegradable packaging is an essential shift in how we value resources instead of just a technological substitute for plastic. The fashion and packaging sectors may create a closed loop system that replenishes the ecosystem with nutrients instead of enhancing landfill degradation by combining polymer innovation with textile waste valuation.

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