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# Biodegradable Packaging in Medical Field

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**Abstract:** *An Ecological Method for Biological Packaging in the Drug Industry The pharmaceutical industry is coming under increasing pressure to utilize eco-friendly packaging. Traditional packing materials often contribute to pollution and resource depletion. A good alternative is packaging composed of biodegradable and compostable materials derived from renewable resources. This study looks at the state of biological packaging in the pharmaceutical industry today, focusing on materials, procedures, and their potential impacts on sustainability and product integrity. We go over the potential and difficulties of implementing biological packaging, such as customer acceptance, cost-effectiveness, and regulatory issues. We also highlight new developments and potential paths in this area, like the creation of cutting-edge biomaterials and creative packaging designs.*

*Pressure to implement sustainable practices is mounting on the pharmaceutical business, especially in packaging, where non-biodegradable materials and plastic waste are major environmental concerns. With advantages for the environment and functionality, biodegradable packaging offers a viable answer to this problem. This review examines the latest developments in biodegradable packaging materials, with a focus on pharmaceutical applications.*

**Keywords:** Ecological Method

## I. INTRODUCTION

The pharmaceutical industry sits at the nexus of scientific advancement, global healthcare, and economic vibrancy. From the rudimentary apothecaries of the past to the highly advanced and regulated profession it is now, the medical industry has redefined the boundaries of medical research throughout its history. Pharmaceutical companies have transformed healthcare by creating drugs and therapies that improve quality of life, increase lifespans, and combat once-fatal diseases. Their relentless pursuit of information and technological advancement drives their work.

Simultaneously, the industry has enormous commercial weight, making a substantial contribution to the world economy, employing millions of people, and participating in intricate supply chains that cross continents. This industry is defined by fierce rivalry

stringent laws, significant R&D expenditures, and a never-ending struggle to strike a balance between innovation, accessibility, and profitability.[1].

In the EU, packaging trash accounts for around 67 million tonnes per year, or almost one-third of all municipal solid garbage. Packaging accounts for 3.2 million tonnes of domestic waste produced annually in the UK, or more than 12% of all household waste produced. Sixty percent of packaging used in wealthy nations is for food. The primary causes of this are the stringent laws governing food packaging as well as the desire to improve look in order to boost sales. The percentage of food that is unfit for consumption before it reaches the customer is 2% in the UK, but it can be as high as 40% in poorer nations where packaging is less common.

Metal, glass, wood, paper or pulp-based materials, polymers, or composites made of many components are just a few of the materials utilized in packaging applications. [2]. Department of pharmaceutics

**The development of biodegradable packaging aims to achieve two goals:**

- Using raw materials from renewable and potentially more sustainable sources (crops rather than crude oil).
- Facilitating integrated waste management systems to minimize landfill trash. Studying how these biodegradable packaging materials affect waste management is obviously crucial to understanding their true



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benefits and the necessity of putting in place suitable waste management laws and procedures.

- Biodegradable packaging disposal and waste management Traditionally, plastic packaging wastes in the UK were dumped in landfills because of the challenges associated with sorting and moving such a huge quantity of lightweight materials in contaminated and mixed forms.[3].
- Biodegradable packaging materials create additional avenues for waste treatment and may be included in the composting or waste water system.To ensure equal levels of performance and cost, new biodegradable packaging must be used in place of traditional packaging. Nonetheless, bio-based films frequently exhibit inadequate mechanical, thermal, and barrier qualities. Many studies have therefore concentrated on coming up with fresh ideas for producing materials that have the right properties to take the place of traditional packaging materials.
- In the pharmaceutical industry, packaging is essential to ensuring the efficacy, stability, and safety of medications. It's more than just containment. Packaging serves a number of purposes, including as protecting fragile items from light, moisture, and oxygen, facilitating accurate dosage, and enhancing patient compliance.
- Biodegradable packing materials are composed of naturally occurring polymers. During composting operations, these microorganisms—which include bacteria, fungi, and algae—should be able to convert these polymers into naturally occurring breakdown products such carbon dioxide, water, methane, and biomass. There are two types of biodegradable polymers: edible and non-edible. Due to their potential to replace traditional plastics and serve as edible coatings or films that come into contact with food, edible biodegradable polymers derived from proteins, lipids, and polysaccharides—ingredients found in food—have recently attracted a lot of attention. [2].

## II. IMPORTANCE OF SUSTAINABLE PACKAGING

As the need for environmentally friendly methods grows, businesses worldwide are becoming increasingly concerned about sustainable packaging. Using sustainable solutions is essential in the pharmaceutical industry, as packaging protects the efficacy, safety, and purity of medications.

- **Environmental Impact**: Plastics and other traditional packing materials significantly raise global pollution levels. Sustainable packaging, like biodegradable materials, reduces its environmental impact by reducing waste and promoting decomposition.
- **Regulatory Compliance**: Governments and organizations are implementing stricter regulations to decrease non-biodegradable waste. Pharmaceutical companies can use sustainable packaging to meet these regulations and avoid issues.
- **Biodegradable packaging**: The pharmaceutical business is clearly shifting toward the use of biodegradable packaging materials in response to the growing demand for eco-friendly practices.
- These materials offer a sustainable substitute for traditional packaging, which usually has long-lasting negative environmental effects, because they are designed to decompose organically over time. [5].
- **Reusable Packaging**: One important advancement in pharmaceutical packaging methods is the increasing adoption of reusable packaging concepts. This strategy modification aims to lessen the impact on the environment by developing packaging options that may be used repeatedly for different pharmaceutical products or the same product.
- For items like inhalers or other medical devices that are crucial to treatment regimens, this approach is particularly pertinent. Pharmaceutical companies that put an emphasis on reusability not only contribute to waste reduction but also uphold the principles of the circular economy.
- **Smart Packaging for Reduced Waste**: The advent of smart packaging technologies, which put sustainability first, is revolutionizing the pharmaceutical packaging sector
- By adding intelligent components like sensors and data tracking, businesses may enhance inventory management, avoid overpackaging, and guarantee the maximum freshness and efficacy of pharmaceutical products. Reducing needless waste not only increases operational efficiency but also makes a substantial contribution to sustainability goals.

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- **Regulatory Compliance**: As environmental awareness grows around the world, regulatory agencies are focusing more on sustainable pharmaceutical sector practices. [24].


**Fig. 1 Biodegradable Packaging.**

## ISSUES WITH TRADITIONAL PHARMACEUTICAL CONTAINERS

Traditional pharmaceutical packaging has several drawbacks. Environmental Pollution: A significant amount of waste accumulates because most pharmaceutical packaging, such as plastic sachets, blister packs, and containers, is not biodegradable.

- **Resource Intensity**: Fossil fuels and other non-renewable resources are widely used in the production of conventional packaging, which leads to resource depletion and greenhouse gas emissions. [24].
- **Restrictions on Recycling**: Many common materials, such as PVC and multi-layer polymers, are difficult to recycle due to their complex compositions.
- **Issues with Regulation and Disposal**: Inappropriate disposal of pharmaceutical packaging can contaminate ecosystems, affecting soil, water, and animals. Additionally, the disposal process is made more challenging by the need to manage medical waste carefully. Department of pharmaceutics

## THE PROJECT'S GOALS ARE TO:

- **Examine Biodegradable Pharmaceutical Packaging Alternatives:** Before using biodegradable materials for primary and secondary pharmaceutical packaging, they must be found and evaluated to ensure that they meet strict standards for the safety, stability, and protection of pharmaceuticals.
- **Analyze how biodegradable packaging affects medication stability and safety:** To investigate how biodegradable materials affect the quality and efficacy of pharmaceuticals over time, accounting for variables such as light exposure, humidity, and climate sensitivity.[6].
- **Take into account the following advantages of biodegradable packaging for the environment:** To carry out a lifecycle study that contrasts the environmental effects of traditional plastic packaging with biodegradable packaging, focusing on elements like carbon footprint, waste reduction, recyclability, and biodegradability.
- **Examine Industry Standards and Regulatory Compliance:** To investigate current pharmaceutical packaging regulations and assess how well biodegradable materials meet the requirements for medication packaging established by the Food and Drug Administration, the European Medicines Agency, and other regulatory bodies. [23].
- **Offer a Practical Implementation Strategy:** To offer a practical and affordable strategy that considers production costs, material sources, and potential operational challenges in order to help the pharmaceutical sector transition to biodegradable packaging.[7].
- **Analyze the costs and benefits:** to evaluate the financial feasibility of employing biodegradable packaging, taking into account the initial investment, continuing waste management savings, and potential market advantages associated to sustainability.
- **Analyze industry trends and case studies:** to examine case studies and actual instances of pharmaceutical companies who have already begun utilizing biodegradable packaging, understand the challenges they have faced, and offer suggestions for future implementation. [8].

## III. PACKAGING

Packaging of product done to deliver the product in correct way to patient or any customer without damaging it during the transportation.

**Types of packaging**

- **Primary packaging** -which customers typically take home with them and come into contact with the items in. Ex: bottles, ampoules etc.
- **Secondary packaging** -which includes the bulkier packaging like boxes that is utilized to transport primary packaged goods in quantity. Ex: Boxes, cartons etc.
- **Tertiary packaging** -which includes plastic wrapping and wooden pallets is packaging designed to facilate the transportation of large no of goods .Ex :wood -pallets

Because secondary and tertiary packing materials are typically found in higher quantities and with less diversity in their composition, wholesalers and retailers find it easier to collect and sift them for recycling or reuse. Primary packaging materials present challenges for recycling or reuse because they are not only more widely distributed throughout homes but also heavily mixed, polluted, and frequently damaged.

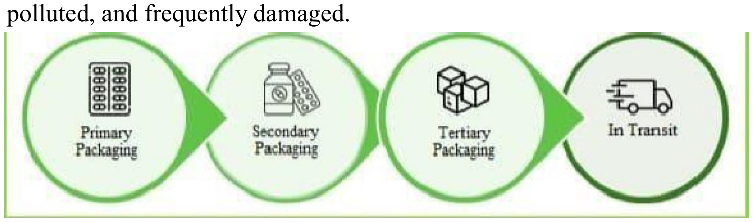


**Fig. 2 Types Of Packaging.**

**FUNCTIONS OF PACKAGING**

- **Barrier protection:** Blister packaging (Pharma grade barrier film and eco-friendly halogen free film) can be used to provide this kind of protection against all harmful external influences that can change the product's properties, such as moisture, light, oxygen, and temperature fluctuations.
- **Biological protection:** Its purpose is to safeguard against biological contamination. **Physical protection:** Is intended to shield medicinal dosage forms against physical alterations.
- **Information communication:** Information about the proper use of dosage forms, their contents, their provainance, adverse effects, and warnings should be included on pharmaceutical packaging.
- **Identification:** its purpose is to identify the product.
- **Security:** Pharmaceutical packaging has specific characteristics that keep forgery at bay.Additionally, it keeps young children from obtaining the formulation's contents.
- **Convenience:** Packaging needs to be user-friendly enough to improve distribution, handling, selling, and product use while also increasing customer access to the product.[14].

**Types of Packaging Material**

**Glass**-It has been widely used for packaging composed of soda ash and lime stone. They have good protection and easily labeled. But they are breakable and heavier than plastic. There are four types of glass

| | |
|---|---|
| Type-1 | Borosilicate glass |
| Type-2 | Treated soda lime glass |
| Type-3 | Regular soda lime glass |
| Type-4 | NP glass |

**Plastic** –Synthetic polymer of high molecular weight light in weight and easily handled unbreakable and available in various shapes and size but poor conductor of heat and easily permeable to water and air. There are two types of plastic

| | |
|---|---|
| Thermoplastic | Ex: polyethylene, PVC, Polystrene |
| Thermosetting | Ex: Silicone, Polyurethane and Phenolic |

**Metals**- Metal containers used for product which required additional protection from light and moisture Ex: Aluminium, tin

**Paper**-Paper commonly used in packaging of solid material. Ex: coated paper ,cardboard, craft paper.

In the pharmaceutical sector, packaging plays a crucial role in guaranteeing the safety, stability, and effectiveness of pharmaceuticals. It goes beyond simple containment. Packaging has a variety of functions, including safeguarding delicate goods from the elements (light, moisture, and oxygen), making dosing precise, and improving patient compliance. Many national or international associations have been founded to promote the development of biodegradable packaging materials made from renewable natural resources, and governments in EU member states have recently extended broad support to this effort.[16].

**THERE ARE SOME BIODEGRADABLE MATERIALS FOR PHARMACEUTICAL PACKAGING**

To guarantee that pharmaceutical packaging satisfies the necessary requirements for drug safety, stability, and environmental sustainability, biodegradable materials must be chosen. [8].

**A. Polylactic Acid (PLA)**

- **Overview:** Made from renewable materials like sugarcane or maize starch, polylactic acid (PLA) is a thermoplastic polymer that is both biodegradable and compostable. In many different industries, it is one of the most popular biodegradable materials.
- **Biodegradability:** Under composting conditions, PLA breaks down microbially into carbon dioxide and water. It decomposes in a year or two.
- **Mechanical Strength:** PLA is appropriate for packaging applications requiring structural integrity because it is robust and long-lasting.
- **Transparency:** PLA may be made transparent, which is essential for pharmaceutical packaging since it lets customers see the product inside.
- **Barrier qualities:** PLA has strong oxygen and moisture barriers, which are critical for preserving the stability and effectiveness of pharmaceutical goods.
- **Thermal Properties:** PLA's employment in applications involving high-temperature operations may be restricted due to its poorer heat resistance when compared to conventional plastics. [6].

**Application:**

- **Blister Packs:** To safeguard specific medication dosages, PLA might be utilized in blister packs.
- **Bottles & Containers:** PLA can be shaped to fit medicinal items, whether they are liquid or solid.
- **Films and Labels:** Because PLA is printable and can be made to easily communicate with consumers and brand products, it may be used to make packaging films and labels.
- **Benefits:** Made from plant-based resources, it is renewable.Compostable in industrial composting settings and completely biodegradable.
- **Limitation:** Not as heat-resistant as polymers made from petroleum.Its efficacy in some settings is limited since it requires industrial composting for full breakdown.[12].

**B. Polyhydroxyalkanoates (PHA)**

- **Overview:** Microorganisms manufacture a family of biodegradable polymers called polyhydroxyalkanoates (PHA). PHAs are extremely adaptable for environmentally friendly packaging solutions because they are made from renewable materials and totally decompose in both aerobic and anaerobic settings.
- **Biodegradability:** PHAs completely break down in composting, soil, and water. Depending on the particular kind of PHA, degradation rates can differ.
- **Mechanical Strength:** PHAs have strong mechanical strength, toughness, and flexibility—all of which are critical for the long-term viability of pharmaceutical packaging.
- **Biocompatibility:** Because PHAs are biocompatible, they can be used in pharmaceutical and medical settings, including as in drug delivery systems and packaging materials that come into direct touch with medications.

Excellent gas and moisture barriers are provided by PHAs, which are crucial for preserving the stability and shelf life of medicinal items. [1].

- **Application:** Packaging Films: PHA can be utilized to create flexible films for pharmaceutical wraps, sachets, and pouches.
- **Containers:** PHA is used to make stiff medicinal containers like jars or bottles.

**Applications in Medicine and Drug Delivery:** PHA's biocompatibility makes it suitable for certain uses in drug delivery systems and medical packaging. [19].

- **Advantages:** Fully biodegradable in soil and water, two natural habitats.made from biomass that is renewable can be modified using different chemical architectures for certain uses.
- **Limitation:** More expensive to produce than conventional polymers. restricted large-scale commercial production and availability.[11].

**C. Starch-Based Bioplastic:**

- **Overview of Starch-Based Bioplastics**: These bioplastics are made from starch, which is usually taken out of crops like potatoes and corn. These bioplastics can be processed to create biodegradable films, foams, and coatings that are appropriate for a range of packaging uses.
- **Biodegradability:** Under industrial composting conditions, polymers based on starch can break down. In certain situations, they can break down in water or soil in a matter of weeks or months.
- **Mechanical Properties:** Although starch-based polymers can be made lightweight and flexible, they lack the strength and durability of some other biodegradable plastics. To increase their strength, they might need to be used with other substances.
- **Water Sensitivity:** Starch-based polymers may not function as well in humid environments due to their sensitivity to moisture. By mixing them with other biopolymers or adding plasticizers, this can be lessened.
- **Thermal Properties:** Generally speaking, they are more suited for low-temperature applications due to their lower thermal resistance.[10].

**Application:**

- **Packaging Films:** Bioplastics based on starch can be used for outer packaging films, such as blister packs or wraps for pharmaceutical bottles.
- **Coatings:** Used to coat pills or tablets to protect the active ingredientS
- **Foam Packaging:** Can be processed into foam for use in cushioning pharmaceutical products during transportation.
- **Benefits:** Low cost because raw materials like corn and potatoes are readily available. Easy to compost in industrial composting systems.potential for use in both flexible and rigid packaging.
- **Drawbacks:** Sensitivity to moisture and humidity. less strength and durability than PLA and PHA. may need additives to improve performance for pharmaceutical packaging.[9].

**D. Cellulose-Based Plastics (Cellophane)**

- **Overview:** Natural cellulose, which comes from wood pulp, cotton, or other plant resources, is used to make cellulose-based plastics like cellophane. One of the first types of biodegradable plastic, cellophane is still widely used in food and medicine packaging.
- **Biodegradability:** Under normal circumstances, plastics made of cellulose are completely biodegradable and compostable.
- **Mechanical Strength:** Cellophane can be used to package delicate goods like medications because of its strength and good resistance to tearing**.**
- **Transparency:** For pharmaceutical packaging that is intended for consumers, cellophane provides exceptional clarity.

Excellent barrier qualities against air, oils, and greases make cellophane a great choice for preventing contamination of medicinal items. [26].

**Application:**

- **Blister Packs:** Cellophane is frequently used to make blister packs for tablets, capsules, and pills. Sachets: Cellophane can be used to package individual pharmacological doses in single-dose containers, offering a barrier of protection. Cellophane is used as an outer wrap or seal for pharmaceutical items that need to be packaged in a way that makes them impossible to tamperwith.
- **Benefits:** Made from plant resources, renewable.both compostable and biodegradable. offers a superior defense against impurities.
- **Difficulties:** To improve moisture resistance, more coating or treatment can be needed. restricted flexibility in contrast to PLA and PHA, two other biodegradable polymers. [26].

**Fig. 3 Eco-friendly pharmaceutical packaging**

**E. Chitosan**

- **Overview:** The biopolymer chitosan is made from chitin, which is present in the shells of crustaceans such as crabs and shrimp. Chitosan is utilized in many packaging and biomedical applications because to its exceptional biodegradable qualities.
- **Biodegradability:** In natural settings like soil and water, chitosan is fully biodegradable.
- **Natural antibacterial Properties:** Chitosan's antibacterial qualities might be advantageous in pharmaceutical packaging, where sterility is crucial.
- **Capacity to Form Films:** Chitosan has the ability to create thin films that can be employed as a protective coating on pharmaceutical items.
- **Mechanical Properties:** Although chitosan-based films are flexible, they might need to be blended with other materials or crosslinked to increase their strength. [13].

**Application:**

- **Antibacterial Packaging:** Chitosan's antibacterial qualities make it suitable for packaging delicate medicinal items that need extra defense against bacterial contamination.
- **Tablet and capsule coatings:** Chitosan is frequently used to tablets as a coating because it offers protection and the possibility of regulated release of active substances.[15].

**Advantages:**

- Non-toxic and biodegradable
- The integrity of the product is preserved by its antimicrobial qualities.
- Made from marine-based, sustainable resources

**Difficulties:**

- Due of restricted supply, it may be pricey.
- Limited scalability for commercial production on a big scale. [25].

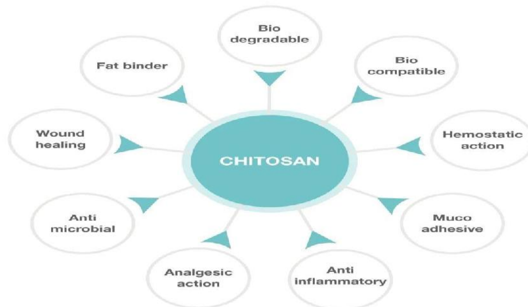


Fig. 4 Chitosan as Packaging material.

## IV. MANUFACTURING PROCESS

**Conversion technologies :**

Rethinking manufacturing methods is necessary to make the switch from conventional to biodegradable materials. For raw biopolymers to be converted into useful packaging, conversion methods are essential. Biopolymers are being adapted for injection molding, blow molding, extrusion, and thermoforming, which calls for modifications to processing variables like cycle periods, pressure, and temperature. These changes guarantee the best possible material flow, crystallinity, and product quality.

Innovative technologies :Additionally, new technologies are emerging that allow for the creation of complicated geometries and improved performance characteristics, such as nanocomposites and three-dimensional (3D) printing. These developments, which provide previously unheard-of levels of personalization and design flexibility, are influencing the direction of pharmaceutical packaging. [22].

**Life cycle analysis :**

Life cycle analysis (LCA) has emerged as a crucial instrument for evaluating the environmental impact of biodegradable packaging. From the extraction of raw materials to manufacture, usage, and end-of-life management, life cycle assessment (LCA) looks at every step.

The degradability of the material is simply one aspect of a thorough life cycle assessment (LCA); other factors include energy use, water footprint, greenhouse gas emissions, and social ramifications. By taking a comprehensive approach to material selection, design, and decision making, it is ensured that the goal of biodegradability does not unintentionally result in additional environmental costs.[4].

**Performance :**

The exacting performance requirements established by conventional materials must be fulfilled by biopolymers. Careful attention must be paid to factors such mechanical strength, barrier qualities, moisture sensitivity, and thermal stability. It takes careful formulation, processing, and testing to strike a balance between these performance characteristics and biodegradability.

**Cost :** One major obstacle is still the greater production cost of biopolymers as compared to traditional plastics. Research, development, and scale-up investments are necessary to lower. 28].

## V. FUTURE ASPECTS OF BIODEGRADABLE PACKAGING IN PHARMACEUTICLS

**Technological advancement in biodegradable materials:** The range of practical materials for pharmaceutical packaging is anticipated to increase with the introduction of new biodegradable polymers and composites.

It is projected that advancements in bioplastics, including biodegradable cellulose and polyhydroxyalkanoates (PHA), would increase the robustness, adaptability, and affordability of packaging materials. These developments will aid in overcoming some of the present drawbacks of biodegradable materials, including their decreased strength and resilience to moisture.[5].

**Increased regulatory support and standards**: Regulatory agencies like the FDA and EMA are probably going to implement stricter guidelines and incentives for sustainable packaging as governments around the world place a greater emphasis on environmental sustainability.

This could involve standards for waste reduction, compostability certifications, and rules for the usage of biodegradable products. Eco-labeling and other regulatory benefits that demonstrate corporate responsibility may also be advantageous to pharmaceutical companies that use biodegradable packaging.[21].

**Integration with circular economy models:** The pharmaceutical sector is adopting the ideas of the circular economy, which calls for resources and goodsto be recycled, repurposed, or composted instead of being thrown away. This strategy might easily include biodegradable packaging, which would enable pharmaceutical companies to shut the loop by creating goods that, when used, break down into innocuous components, lessening the load on landfills. Pharmaceutical businesses will probably be able to include their packaging into more comprehensive sustainability initiatives because to advancements in packaging design. Consumer demand and corporate social responsibilities:

Customers and medical experts are calling for more sustainable products as they grow more aware of environmental challenges. Pharmaceutical businesses are realizing that using biodegradable packaging improves their brand image and market appeal in addition to helpingthe environment. Pharmaceutical businesses may get a competitive edge in the market by showcasing their dedication to sustainability through the use of biodegradable packaging.[20].

**Cost and performance improvement:** The cost difference between biodegradable and conventional packaging materials has been a major obstacle to the broad use of biodegradable packaging in the pharmaceutical industry.

However, it is anticipated that the price of biodegradable packaging will drop as production technologies advance and economies of scale are realized. The performance of biodegradable materials is also being improved by ongoing research to satisfy the strict standards of the pharmaceutical sector regarding drug safety, storage, and preservation.

**Global sustainability initiative:** Environmentally friendly methods are being pushed by growing awareness and international programs like the European Union's Green Deal and the Sustainable Development Goals (SDGs) of the United Nations.

As part of their larger environmental strategy, more pharmaceutical businesses will probably investigate and implement biodegradable packaging options as a result of these initiatives.[18].

**Collaboration and industry partnership:** Pharmaceutical businesses, package producers, material scientists, and regulatory agencies will need to work together to make the switch to biodegradable packaging in the pharmaceutical sector. For the development and adoption of novel packaging technologies that satisfy sustainability and performance standards, collaborations throughout the supply chain will be essential. 27].

## VI. CONCLUSION

In the pharmaceutical sector, biodegradable packaging offers a viable way to address the mounting environmental issues related to conventional plastic packaging. In addition to lessening the environmental impact, the move to sustainable materials like plant-based polymers, bioplastics, and edible films also bolsters the industry's dedication to corporate social responsibility. The adoption of biodegradable alternatives presents special problems for the pharmaceutical industry, which is renowned for its stringent regulatory standards and sensitivity to product purity. These challenges include cost, durability, and regulatory compliance. However, biodegradable packaging has the potential to completely transform the market with improvements in material science and greater cooperation between producers, legislators, and environmental specialists.

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