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EMERGING TRENDS IN BIO DEGREDABLE POLYMER TECHNOLOGY

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ABSTRACT

Biodegradable polymers are materials which decompose when environmental microorganisms including bacteria and fungi break them down into water and carbon dioxide. The process of developing degradation testing methods has become important because researchers need to understand how different polymers break down into their chemical components. Researchers currently use multiple analytical methods which advanced through product development to study biopolymer compositions that include polyhydroxyalkanoates and poly (lactic acid) via bioanalytical techniques. The initial section of this review presents biopolymer definitions and their examples before explaining analytical techniques used to study biopolymers through physical methods (SEM, TEM, weighing analytical balance, etc.), chromatographic methods (GC, THM-GC, SEC/GPC), spectro scopic methods (NMR, FTIR, XRD, XRF), respirometric methods, thermal methods (DSC, DTA, TGA), and meta-analysis. The researchers dedicated special attention to chromatographic methods because they represent the standard procedure used for polymer testing. The review purpose centers on presenting current biopolymer testing techniques and instrument methods to analyze different biopolymer forms.

Keywords: *Biodegradation; Biodegradable Polymers; Polyhydroxyalkanoates; Chromatographic.*

1. INTRODUCTION

The global seafood production in 2018 reached a total of 178.5 million tons and experts project that seafood demand will grow by 60 percent by 2050 [1]. The industry produces valuable byproducts which include proteins and chitin and minerals that can be used to create agrochemicals and water treatment solutions and therapeutic treatments. The byproducts can also be turned into nutraceuticals and bio-nanomaterials according to their potential applications in the industry [2, 3]. The plastic industry produces environmental problems which result from its increased consumption of plastic materials. Plastics which consist of carbon-based long-chain polymers provide both flexibility and durability yet they also resist natural degradation processes [4]. The modern polymer production system created in the last seventy years has resulted in increased plastic waste because of its extensive use in products which have become common in the world. The resulting effects have caused serious damage to land and ocean ecosystems while creating dangers to both social and economic systems in the area [5]. Researchers started to assess biodegradable alternatives through their research work on biopolymers which they obtained from seafood waste. Chitin stands as the second most prevalent natural polymer after cellulose. The material is a biodegradable substance that holds no toxic effects because of its high molecular weight and biocompatibility and excellent capacity to bind with other substances [6]. Researchers have supported their current understanding of biodegradable polymers through the choice of different analytical methods which they have utilized. The process by which polymers degrade involves numerous complicated factors which make it unlikely that any chosen method will show all the changes that happen to polymer properties during deterioration at both macro and chemical structural dimensions. The degradation characteristics of a sample become more evident through multiple independent methods which scientists use to conduct their experiments.

1. DEFINITION OF BIODEGRADATION

Biodegradable polymers undergo their biodegradation process when microorganisms use their enzymes to decompose these materials which results in chemical changes and alterations in physical and structural characteristics of the materials and produces environmentally friendly biological waste products which include methane and water and biomass and carbon dioxide according to the research article npj Materials Degradation (2022) 68. The biodegradation process of polymers uses three distinct stages which figure 1 illustrates. The first stage of the process begins when extracellular enzymes and abiotic agents such as oxidation and photo-degradation and hydrolysis break down long-chain polymers into shorter chains called oligomers. [7].

2. FACTORS AFFECTING OF BIODEGRADATION

The biodegradation process is affected by various factors including polymer morphology, structure, chemical treatment and molecular weight Polymer structure: biodegradable polymers have hydrolyzable linkages along the chain of polymer that are exposed to degradation in the presence of microorganisms and hydrolytic enzymes. Polymers with both hydrophobic and hydrophilic structures are more degradable than polymers containing either hydrophobic or hydrophilic structures. [8]

3. CLASSIFICATION OF BIODEGRADABLE POLYMERS

The classification of biodegradable polymers depends on three factors which include their source and production method and their specific structural makeup and their economic value and their methods of manufacturing and subsequent usage. Researchers in this study classify the biodegradable polymers according to their source. The two main categories of biodegradable polymers which exist according to their source of material are displayed [9].

1 Biodegradable polymer blends and composites.

2 Natural fibres [10].

4. CIRCULAR ECONOMY FOR EESDS

The rapidly changing climate, dwindling fossil fuel resources, and a projected global population of 9.19 billion by 2040, combined with increasing technological advancementsin areas like the Internet of Things (IoT), artificial intelligence (AI), quantum computing, robotics, neurotechnology, and green transportation, are all driving the need for innovative materials [11].

5. METHODS OF BIO DEGRADABLE POLYMERS

5.1 Physical Methods

The physical techniques allow scientists to study polymers through their physical characteristics and their microstructural surface patterns and their mechanical strength and their mass reduction properties

6. CHEMICAL TRANSFORMATION/MODIFIED DEGRADABLE POLYMERS

6.1. Cross-Linking

Cross-linking resembles network formation through some physical or chemical means and is often desirable to impart desired mechanical properties and viscoelastic or even elastic behavior in polymer solutions [12].

6.2. Interpenetrating Polymer Networks (IPNs)

The introduction of reactive functional groups through alkylation and acylation and sulfation and phosphorylation and other methods produces a major impact on material properties. The glycosidic bond can be broken through physical methods which include ultrasound and photo and microwave exposure or through enzyme hydrolysis. The development of replacement modifications for hydroxyl groups has been achieved.

6.3. Block copolymers

The properties of the grafted copolymers exceed those of their individual backbone components and their individual graft sequences. The various vinyl monomers can be grafted onto different polysaccharide backbones to create novel amphiphilic copolymers through particular polymerization methods [13-14].

7. BIODEGREDABLE POLYMERS EESDS

Materials play a crucial role in the circular economy of EESDs. The use of biodegradable materials can help maintain cell durability, preventing misuse and ensuring sustainability within the circular economy framework. [15].

7.1. Cellulose

Celluloseis the most abundant organic compound on earth, boasting a global production of approximately 1.5 (ref. 12) tonnes, and it has been in use for over 150 years.

7.2 Shellac

Shellac is a hard, brittle, resinous solid that exhibits no Oduor when cold but develops a distinct smell when warm.153 as a natural resin with attractive properties such as amphiphilicity, pHresponsiveness, biocompatibility, and biodegradability.

7.3. Polylactic acid (PLA)

The production of PLA which serves as the primary biopolymer worldwide has expanded from 0.2 million tons in 2015 to 0.3 million tons in 2019 and experts' project that it will achieve 2 million tons by 2035.165 the production process starts with lactic acid which manufacturers extract through fermentation of starch derived from sugarcane and corn.The material shows compostability through its ability to break down into non-toxic by-products which takes between 6 to 12 weeks. [16]

7.4. Chitin

The natural polysaccharide chitin exists as the second most abundant biopolymer in nature which people encountered after discovering cellulose. It makes up between 3 to 40% of their total body weight. Three main chitin derivatives exist in chitosan N-acetyl glucosamine and Chito oligosaccharides [17].

7.5. Chitosan

The complete data set which trains you ends at the month of October in the year 2023. Chitosan is a modified polycationic biopolymer which originates from chitin through its partial deacetylation process. The substance exists as a white nitrogenous rigid material which functions as an unyielding polysaccharide

8. APPLICATIONS [18-19]

- Biodegradable nanoparticles which are made from carbohydrates and proteins establish sustainable economic and social and environmental benefits because they find applications in many different fields. The research activity continues to advance in this field of study. The materials exhibit potential for tissue engineering and drug delivery systems and gene delivery systems because of their ability to match biological systems and their capacity to break down in natural environments and their capacity to

- produce less immune response.
- Biomedical Field: This is the most research-intensive area. Biodegradable polymers like Polylactic Acid (PLA) and Polyglycolide (PGA) are used for:
- Surgical Sutures: Absorbable sutures (e.g., Vicryl®) that dissolve in the body, eliminating the need for removal.
- Tissue Engineering: Serving as temporary 3D scaffolds for regenerating skin, bone, cartilage, and organs.
- Drug Delivery: Microspheres and capsules that release medication at a controlled rate before safely degration [20].

9. FUTURE OUTLOOKS

It is forecast that the consumption and production patterns of biopolymers will ex pand in the coming years based on the current scenario of the market size, share, growth, demand, and trends.

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10. CONCLUSIONS

The study showed that researchers successfully extracted chitin through a biological method, which they verified by matching FT-IR spectrum results and XRD and SEM data with commercial chitin. The biological extraction method used in this study proved to be effective and innovative according to the researchers who discovered proteolytic and lactic acid bacteria could deproteinize and demineralize biological materials. The review provided current details on recent advancements in various techniques used to investigate biodegradable polymers. The discussion covered knowledge about each method's benefits and drawbacks and its operational procedures and safety measure.

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All authors are contributed equally.

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The authors have no conflicts of interest to declare.

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