



(REVIEW ARTICLE)



## A review on vegetable oil based biodegradable polymers

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### Abstract

The reviewed work addressed the shift in focus from conventional polymers to bio-based and renewable polymers. This extensively discussed the values of various fatty acid components present in the oils and polymers. Areas of application of the thermosetting polymers obtained from plant seed oils were discussed. Non-biodegradable polymers are causing severe damage to the environment. To counter this, need of biodegradable polymers is gaining a rapid growth in numbers, in their applications and quantities used. In this manuscript, we have briefly described important vegetable oil derived materials such as alkyds, poly-esteramides, polyurethanes, epoxies, polyols, along with their preparation and applications as protective coatings. A small portion of the review is also dedicated to the future perspectives in the field. In spite of their extensive utilization in the world of coatings, literature survey revealed that in the past no review has come up describing the chemistry and applications of vegetable oil polymer based coating materials.

In addition, due to the oil crises worldwide, focuses from synthesizing polymers from petroleum has shifted to the synthesis of polymers from renewable resources such as vegetable oils. The use of vegetable oils in the polymer renders biodegradability to the polymer. Different researchers have used different vegetables oils like castor oil, soybean oil, & sunflower oil for synthesis of polymers and utilized them in diverse fields like biomedical, coatings, adhesives, and as structural materials. This review discusses the synthesis, characterization, degradation and applications of polymers obtained from natural oils such as castor oil, soybean oil etc.

**Keywords:** Vegetable oil; Fatty acid; Biodegradable polymer; Polymer application

### 1. Introduction

Polymers are used for varied technical functions, reckoning on their diversifying properties. Massive range of useful variations and behaviors has made them helpful in an exceedingly large kind of applications.

The monomer and architectural organization of the macromolecules at the same time decide the dominating properties of the polymers. The endless numbers of choices for making or modify polymers have created these materials enticing to researchers

Among bio-based resources, triglyceride based vegetable oils are vital for polymer synthesis. Vegetable and modified oils are used as main raw materials for resin preparation. Linseed and tung oil are used for coating ingredients in oil paints and varnishes.

These oils are heated thermally to prepare paint ingredients through a reaction known as a Diels–Alder reaction. Sometimes, modifications of nondrying oils by drying oils are found to be fruitful within the preparation of polymers.

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For instance, modified oil was created by an interesterification process with tung oil for the preparation of water-reducible acrylic-alkyd resin. Varied polymerization reactions, as well as cationic, condensation, and radical copolymerization reactions, are accustomed produce varied forms of polymers, like polyesters, polyamides, epoxies, and polyurethanes (PUs)<sup>(1-3)</sup>.

Despite the lack of sufficient literature on the biodegradability properties of vegetable oil-based thermosetting resins, the possibility of cross-linking the carbon-carbon double bonds in polyunsaturated oils through free radical or cationic polymerizations makes the design of bio-based thermosetting polymers from vegetable oils an interesting alternative to petroleum-derived materials biodegradability consists in the breakdown of matter as the result of the activity of microorganisms, such as fungi and bacteria, which typically secrete enzymes that cleave specific chemical bonds or perform very specific chemical reactions, leading to lower molecular weight products that can then be used in other processes, by other organisms<sup>(4-6)</sup>.

In this article, we review the synthesis of vegetable-oil-based polymers of different kinds with different polymerization along with their application.

### 1.1. Types of vegetables oils

Oils are ester compounds and consist of a glycerol molecule linked with three saturated or/and unsaturated fatty acids. Oils can be classified as drying, semidrying, and nondrying, depending on the unsaturation present on them. The chain length or average molecular weight of the fatty acids present in the oil can be determined by the saponification value. The short-chain fatty acids in oil have a higher saponification value, whereas the long-chain fatty acids have a lower value. The density of all oils ranges from 0.80 to 0.95 g/cm<sup>3</sup>, and the specific gravity is around 0.9. All of these properties, directly or indirectly, control the characteristic profiles of polymers produced from vegetable oils.

## 2. Types of biopolymers

In the following subsections, the details of the preparation methods of the biopolymers from vegetable oils, polymerization reactions, advantages and disadvantages, and properties with examples of innovative materials are discussed.

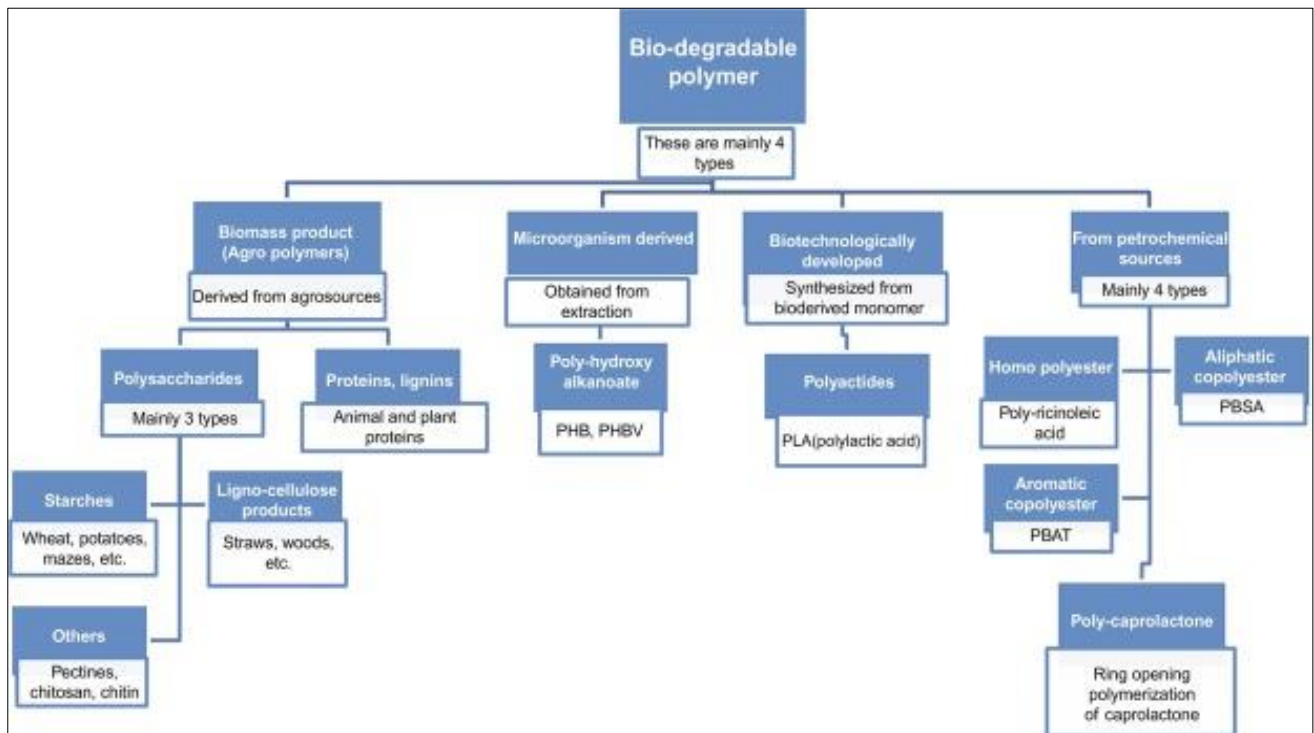


Figure 1 Types of Biodegradable Polymer

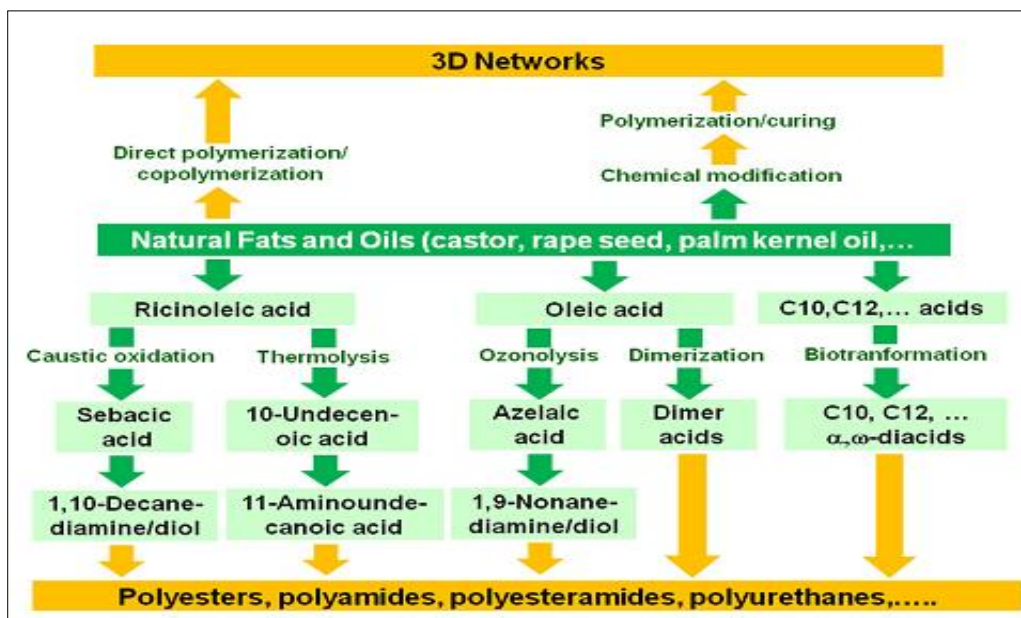


Figure 2 Renewable polymeric materials from vegetable oils

## 2.1. Polyesters

Polyesters have been used as a major binder since the starting of the 19th century because of their excellent auto-oxidative, chemical, and mechanical properties.<sup>7</sup> The general methods for preparing polyesters are the polycondensation reaction of hydroxyl group (AOH) containing organic acids or diacids with a diol and the ring-opening polymerization of lactones.

The common process used to prepare alkyds from plant oils is the monoglyceride method, which includes alcoholysis followed by esterification or polycondensation. In this route, the oil is processed through alcoholysis to produce monoglyceride or diglyceride in the presence of an acid or base catalyst. After this, alkyds are prepared with a polycondensation reaction between monoglycerides and anhydrides. Aromatic polyesters have high heat and moisture resistances compared to aliphatic-based polyesters because of the presence of a stable benzene ring. Additionally, the drying time decreases with increasing anhydride content, whereas maleic anhydride-based resins show minimum drying times compared to the others when the same amount is used. Palm, sunflower, linseed, soybean, rapeseed, jatropha, and rubber seed oils (RSOs) were used to prepare oil-modified polyesters<sup>(7,8)</sup>.

## 2.2. Liquid-Crystalline (LC) Alkyds

The molecules of LC alkyd are mutually aligned and structured (crystal), and the bulk LC polymer shows fluidity in the molten state of the polymer. These resins usually show excellent mechanical performance, low dielectric constant, and high-temperature resistivity.

They are prepared by the following three methods:

- The grafting of p-hydroxybenzoic acid (PHBA) to a hydroxyl-terminated alkyd resin,
- The grafting of PHBA to a carboxyl-terminated alkyd resin, and
- The grafting of PHBA to an excess succinic anhydride-modified alkyd resin<sup>(9)</sup>.

The character of liquid crystallinity was imparted only when at least two or more aromatic units of PHBA were connected to form the rod-like mesogenic side chain. The advantages of LC polymers are the reduced viscosity and the coating's dry-to-the-touch time, and films prepared from them show more hardness and toughness with excellent resistances to water and acid. Moreover, their excellent moldability and heat resistance are also motivational for users.

## 2.3. High-Solid-Content Alkyds

High-solid-content resins are attractive because of technical aspects and economic benefits. They also reduce the use and emissions of volatile organic solvents; this has a negative impact in coating industries. In the development of high-

solid alkyds, the major problem is the reduction of the viscosity without a deterioration of the properties. To address this problem, several theoretical options, such as a narrow molecular weight distribution and an increase in the oil length and the use of reactive diluents can be applied. Another problem, associated with high-gloss decorative paints because of decreasing solvent contents, can be mitigated by the preparation of high-solid-content alkyd resins through a decrease in the molecular weight<sup>(10)</sup>.

#### 2.4. Waterborne Alkyds

Environmental legislation on volatile organic solvent utilization in traditional coatings and their high costs has helped to develop more environmentally friendly and comparatively low-cost coating materials, such as waterborne alkyds. These have been used widely in the past several decades for coating applications. Some other advantages of these materials also have been documented, such as their good resistance to chemicals, heat and abrasion, excellent adhesion, very low VOCs, lower required amount during application (compared to solvent-based materials), easy application and cleaning, and the lack of further additives needed during their use. They exhibit the same properties as organic-solvent-based ones after the evaporation of water from the coating system<sup>(11)</sup>.

Because of the introduction of carboxylic groups, alkyd resins were found to be waterborne. The disadvantages of these kinds of resins include slow drying and tackiness. This problem can be mitigated by the incorporation of melamine or urea formaldehyde during backing at 150C for 2 hrs

Changes in the physicochemical properties and low VOCs with high chemical resistivity were shown by the alkyd emulsions. An inadequate hydrolytic stability is another shortcoming associated with waterborne alkyd resins, and this limits its storage stability. Changes in the physicochemical properties and low VOCs with high chemical resistivity were shown by the alkyd emulsions. An inadequate hydrolytic stability is another shortcoming associated with waterborne alkyd resins, and this limits its storage stability<sup>(12)</sup>.

#### 2.5. PUs

PUs are polymers made from the reaction of diisocyanates and hydroxyl-functional-group-containing compounds or polyols. This kind of polymer was discovered for the first time by Bayer in 1937 through a reaction between a polyester diol and a diisocyanate. Modified oils or triglycerides can be used as polyols to produce a partial glyceride, which may be used in the formulation of Pus

Polymers belonging to this category show a wide range of variations in properties, including density, flexibility, and rigidity; this makes them useful in many application-based products, including foams, varnishes, paint ingredients, adhesives, glues, and matrixes for composites. For example, toluene diisocyanates (TDIs) and methylene diphenyldiisocyanates (MDIs) have been used for flexible and rigid PU products, respectively. Basically, two physical chemical processes are responsible for these wide ranges of properties, that is, phase separation between hard and soft segments and hydrogen bonding between the urethane or carbamate bonds. In addition, the high reactivity of isocyanate, even in a viscous system or at low temperatures, is also responsible for the variations of the properties. A number of research studies, including those of vegetable-oil-based PUs, have been performed in the last few decades. Castor, canola, soybean, sunflower, neem, palm, nahar seed, tung, karanja, and Prosopisjuliflora have been used to produce PU-based polymers. The types of isocyanates and the polyol used in the preparation have the major controlling roles in determining the properties of the formulated PUs. The only disadvantage of these PUs is the inherent toxicity, which is due to isocyanates<sup>(13,14)</sup>.

#### 2.6. Organic-Solvent-Based Pus

Organic-solvent-soluble PUs can be prepared by the reaction between hydroxyl-containing oil or their partial glyceride and diisocyanates. The reaction mechanism is. The fatty acid content in the polyol and the isocyanate (NCO)/OH ratio contributes to the variation of properties of the PUs. To assess their contributions to the dielectric constant and the loss mechanism, palm-oil-based PU was analyzed. A c-relaxation process was proposed as the probable mechanism for the dielectric behavior. The dielectric properties were found to be in the range 2.0–3.0 for the real permittivity and 0.02–0.08 for the imaginary permittivity. At the same OH/NCO molar ratio, a higher Tg, better tensile properties, and a longer elongation break could be achieved because of the introduction of a mild solvent (ethyl acetate) and zinc as a reductive reagent onto the higher triol content canola-oil-based PU.<sup>23</sup> In addition, the hydroxyl functionality (which ranged from 2.4 to 4) also contributed to the good film properties of the PU resin.<sup>25</sup> Additionally, hyperbranching in the PU resins was found to be facilitating in terms of the thermal stability and other film properties compared to the conventional linear-based one<sup>(15,16)</sup>.

## 2.7. Water-Based PUs

Waterborne PU is environmentally friendly. Nowadays, researchers have shown interest in water-based PUs because traditional organic-solvent-soluble PUs pollute the environment through VOC emission during their application and formulation by evaporation processes. Toxic and expensive volatile organic solvents have been replaced by water as an environmentally benign solvent in the formulation of polyurethane dispersions (PUDs), and this has resulted in minimal VOC contents.

Waterborne PUDs can be used in various purposes, including in coatings for various fibers, adhesives for alternative substrates, primers for metals, caulking materials, emulsion polymerization media for different monomers, paint additives, defoamers, associate thickeners, pigment pastes, and textile dyes. Novel biorenewable, waterborne, castor-oil-based PUDs were successfully synthesized via homogeneous solution polymerization in methyl ethyl ketone followed by solvent exchange with water<sup>(17)</sup>.

## 2.8. Interpenetrating Polymer Networks (IPNs).

IPNs are polymer blends and can be prepared by permanent entanglement between two or more distinctly crosslinked polymers. They possess excellent properties because of the interlocking of polymer chains. There are many kinds of IPNs, among which sequential IPNs and simultaneous IPNs are the two most important types. Castor-oil-based PUs and styrene monomers were used to prepare IPNs with tough elastomeric properties. Sequential IPNs were prepared with PU synthesized from canola-oil-based polyol with terminal primary functional groups and poly (methyl methacrylate)<sup>(18)</sup>.

## 2.9. Polyamides

To prepare polyamides, monomer dimer acids (DAs), obtained by the condensation of the C18 acids, such as oleic and linoleic acids of vegetable oils, are required. DAs are environmentally friendly, reactive, nontoxic, biodegradable, and liquid at room temperature and soluble in hydrocarbons. They have higher molecular weights compared to conventional diacids. The preparation of polyamide DA-based polyamides are often compared with traditional monomer-based nylons 6-6 (poly(hexamethylene adipamide)) and have been found to be more flexible, to be more soluble in alcohol, to have a lower melting point, and to possess an average molecular weight. They also show better compatibility with other resins and modifiers. They are useful in many applications, for example, as binders in painting ink, varnishes, and heat-seal coatings<sup>(19)</sup>. In paint systems, thixotropes are prepared from DAs from soybean and tall oil to modify the flow of the paint. Thixotropy is an outcome of weak intermolecular forces in hydrogen bonds.<sup>38</sup> Because of thixotropy, the viscosity of the phthalic anhydride (PA) was found to increase in a state of rest and decrease in constant shear stress.

## 2.10. Poly(ester amide)s (PEAs)

PEAs are regular copolymers of polyester and polyamide, and they have a combination of their properties, including good mechanical properties, high melting temperatures, fast crystallization, excellent solvent resistance, and low water absorption. They usually show better properties in terms of drying time, hardness, and chemical resistivity than polyesters made from the same source. In the preparation of vegetable-oil-based PEAs, pongamiaglabra, coconut, linseed, cottonseed, castor, soybean, neem, nahar seed, and albiziabenth have been studied extensively<sup>(20)</sup>.

## 2.11. Vinyl Polymers Classical Process

Various oils, including drying and semidrying oils, have been polymerized with vinyl monomers because of the easier synthetic process of polymerization. These types of polymers have very good film-forming properties. Drying oils, such as tung oil and low-saturated soybean oil, were used individually with divinyl benzene and polystyrene to prepare polymers as a function of the crosslinking density by a cationic mechanism to evaluate the tribological behavior. Different percentages (10–40 wt %) of concentrations of divinyl benzene were used, and a lower adhesive strength was found due to the higher crosslinking density. In addition, an increased abrasive resistivity was observed because of both the highest and lowest crosslinking densities<sup>(21)</sup>.

## 2.12. Epoxies

Vegetable oils can be transformed into useful polymerizable oxygenated monomers; this is commonly done by Prileshajev epoxidation, catalytic epoxidation with an acidic ion-exchange resin, chemo-enzymatic epoxidation, or metal-catalyzed epoxidation.<sup>59</sup> among these epoxidation methods, chemo-enzymatic epoxidation has achieved considerable interest nowadays because this method is safe and environmentally friendly and the conversion rate of epoxidation usually exceeds 90%

### 2.13. Polynaphthols

The Japanese lacquer (Urushi), a natural product, has been applied as a protective and decorative coating for a huge variety of objects since the Jomon period (10,000–300 B.C.E.) in Japan. The major components of urushi are the urushiols and catechol bearing a C15 unsaturated hydrocarbon chain. For the preparation of the artificial urushi, the plant-oilderived C18 unsaturated hydrocarbon chain was connected with the catechol group through an ester linkage<sup>(22-25)</sup>. In another example, a crosslinkable polymer was prepared from cashew nut shell liquid, whose main component was cardanol (phenol derivative). Cardanol had a metasubstituent of a C15 unsaturated hydrocarbon chain.

## 3. Biobased Polymers

Polymeric materials can be classified into either thermoplastics or thermosetting polymers. Thermoplastic polymers consist of well-packed, non-covalently bound polymer chains that can melt and flow when heated above the polymer's melting point, while thermosetting polymers consist of networks of polymer chains interconnected through covalent bonds. The latter structures do not melt when heated, and cannot be dissolved in a solvent. These differences between thermoplastic and thermosetting polymers have a direct impact on polymer recyclability. It is well accepted that thermoplastics can be easily melted and re-processed during recycling, whereas thermosetting polymers require harsher conditions in order to be converted into other value-added products

Most thermoplastics and thermosetting resins in current industrial use are derived from petroleum, imposing a limitation to the polymer industry due to the continuous depletion of crude oil, frequent oscillation in oil price, and various environmental concerns with sustainability, gas emissions, disposal, and recyclability<sup>(26)</sup>.

biodegradability consists in the breakdown of matter as the result of the activity of microorganisms, such as fungi and bacteria, which typically secrete enzymes that cleave specific chemical bonds or perform very specific chemical reactions, leading to lower molecular weight products that can then be used in other processes, by other organisms<sup>(27)</sup>. There is an intrinsic expectation that novel polymers designed from renewable, and often biodegradable resources, are also biodegradable. Although this is a logical assumption, there is no guarantee that such polymers can be fully biodegradable. Changes in functional groups, crosslink density, and copolymerization with non-biodegradable comonomers can lead to materials that do not necessarily exhibit significant or relevant biodegradability. Therefore, biodegradability studies are crucial in order to assess the long-term environmental impact of bio-based materials

### 3.1. Cashew nut shell Liquid

High temperature processing of CNSL converts anacardic acid into cardanol .CNSL finds use in flame-retardant applications due to its chemical structure, which includes an aromatic ring.Other applications include synthetic polymer, resole and novolac resins, free radical and ionic thermosets, and novel CNSL-formaldehyde resins. Overall, CNSL-formaldehyde resins prepared by various ways have shown inferior mechanical properties.

### 3.2. Vegetable oil

When compared to petroleum-based compounds, the use of natural starting materials for the preparation of bio-based products may result in materials with similar and sometimes possibly improved properties.Therefore, new bio-based materials represent a strategic approach for limiting environmental concern while meeting the current demand for polymers and composites<sup>(28)</sup>.

Recent improvements in the mechanical properties of free radical bio-based composites have been achieved upon use of maleic anhydride as a compatibilizer . Evaluation of the resin composition revealed that conjugated linseed oil (CLO)-based resins exhibit better properties than CSO-based resins due to their higher number of unsaturations . Similar results have been obtained with cationic resins. With a different approach, the thermoset obtained from the ROMP of DCPD and Dilulin® was reinforced with glass fibers. Polyurethane coatings have also been prepared from vegetable oils. As a matter of fact, bio-based polyols can react with diisocyanates to result in polyurethane dispersions (PUDs). Castor oil and ricinoleic acid have been used as starting materials for the preparation of PUDs<sup>(29-30)</sup>. Sunflower, canola, soybean, corn, and linseed oils-based polyols have been used for the synthesis of polyurethanes. Methoxylated soybean oil polyols (MSOLs) , and castor oil-, MSOL-, and AESO-based polyols have been employed in the synthesis of anionic PUDs.

### 3.3. Cellulose and Chitosan

Cellulose and chitin are the most important polysaccharides. Bacterial xanthan gum has been utilized as a bio-based resin. However, not all common polysaccharides are useful as biorenewable polymers. Various approaches have been

investigated for the preparation of composites consisting of cellulose particles embedded in a cellulose matrix<sup>(30-32)</sup>. Invariably, successful composites depend on the solubility of matrix and reinforcement, which can be tuned through pretreatment processing<sup>(33-38)</sup>. Cellulosic matrices have also been reinforced with metal particles for antimicrobial and magnetic applications.

### **3.4. polyhydroxyalkanoates (PHAs)**

Monomer length in polyhydroxyalkanoates (PHAs) depends on the producing bacteria and molecular weights vary with growth medium conditions. For instance, high molecular weight polyhydroxyoctanoate can be produced in diethylene glycol-rich medium. In tissue engineering, PHA composites have been prepared with hydroxyapatite, bioactive glass, and glass-ceramic fillers<sup>(39-44)</sup>. It has been recently shown that the biodegradability of polyhydroxybutyrate (P3HB) and P3HB/valerate copolymers depends greatly on molecular weight, processing conditions, and crystallinity.

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## **4. Application**

Application of Biopolymer are increasing day by day some in the following field of area

### **4.1. Biomedical**

Biopolymers are frequently employed in biomedical applications. They are employed in tissue engineering, pharmaceutical industry, medications, drug delivery, and other applications due to features like degradability and non-toxicity. Polypeptides are cheap and easy to come by, thus they're used in a variety of biomedical products. Systems for delivering drugs- To target the drug and improve medication absorption, biopolymers such as collagen and chitosan are utilized as drug delivery methods. Burn wounds are commonly treated with collagen sponges. Tissue engineering uses both collagen and chitosan. These are extremely permeable, allowing wounds to heal quickly.

### **4.2. Industrial Use**

Biopolymers are used as industry-standard materials due to their unique features. They are coupled with various components to strengthen the qualities of these biopolymers in order to improve their desired features and uses. PHA, polylactic acid, and starch are commonly used in packaging because they are affordable and readily available. They also contain barrier properties that aren't found in other polymers, such as the ability to withstand water. Interior and exterior parts, electrical components, engine, exhaust, steering wheels, and other biopolymers are employed in the automotive industry. To boost the desirable qualities of concrete, biopolymers are added to the cement during the preparation process. They are utilised in the interior decoration building business. Because chitosan possesses capabilities that remove metals from water, it can be used to purify water. It's also used in places to prevent microbe growth because of its antibacterial characteristics.

### **4.3. Agricultural/Fishery**

It is used in making Fishing lines, fertilisers, beehives, nets, traps, etc.

### **4.4. Electronics**

It is used in the manufacturing of audio devices, printed circuit boards, insulated wires, cables and other electronic devices as well.

### **4.5. Cosmetics**

It is well used for cleaning purposes, pedicure and manicure, and also used in cosmetic products such as sunscreen, hair products, creams etc.

### **4.6. Sports/Toys**

It is used in manufacturing of sports equipment such as footballs and other hollow balls, cleats, badminton, golf equipment, etc.

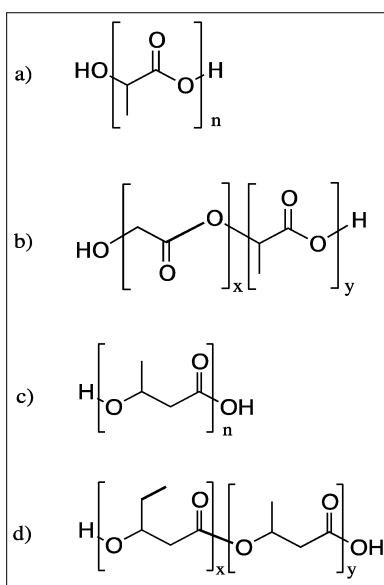
### **4.7. Nanotechnology**

It is also used in the production of nanomaterials. Biopolymers have several special qualities that make them valuable in various fields of science, such as green chemistry.

#### 4.8. Medical Applications

Polymers have been a valuable material in medicine, and over the past half-century, biodegradable, biocompatible polymers have gained increasing popularity in drug delivery. Indeed, bio-based polymers that are capable of dissolving in the body after the drug is delivered to its target are highly desirable. It is possible to design polymers for specific applications by manipulation and control of the polymer composition, thermal behavior, hydrophilicity/hydrophobicity, mechanical properties, ability to retain the encapsulated or entrapped drug, and the interactions of the polymer in a biological environment. Other applications outside the realm of drug delivery include surgical devices, implants, tissue engineering, gene therapy, regenerative medicine, coatings on implant biosensors, and components of diagnostic assays, bio-adhesives, ocular devices, and materials for orthopedic applications.

The applications of a specific bio-based polymer are greatly dependent on its composition. Unsaturated oils have become an attractive source for polymers due to their carbon-carbon double bonds within the fatty acid chains. These double bonds serve as ideal reactive sites for polymerization. Hydrophilicity and flexibility of vegetable oil-based polymers can be tuned by monomer composition and by the selection of the specific oil to be used as a monomer. It has been shown that oil-based polymers do not form uniform blends due to the variable fatty acid composition within each oil, which can result in a micro-phase separation of the matrix, compromising the mechanical properties of the final polymeric material. In order to limit this effect, monomeric triglyceride units have been added to a filler or a template backbone polymer, such as polyanhydrides, co-polyesters, or polyamides. In anticancer treatments, fatty acid dimer (FAD) systems were originally created to control the release of water soluble and unstable chemotherapeutics. Drugs impregnated with FAD were shown to allow for prolonged and controlled drug release. FADs have also been shown to have local anesthetic and antibiotic properties. Most fatty acids undergo condensation to form polyanhydrides that can easily be hydrolytically degraded. Though polyanhydrides can degrade by surface erosion, there are many factors that influence the mechanism and rate of degradation.



**Figure 3** Chemical structures of (a) poly(lactic acid) (PLA); (b) poly(lactic-*co*-glycolic acid) (PLGA); (c) poly-3-hydroxybutyrate (or poly-hydroxybutyric acid, PHB); (d) poly(3-hydroxybutyrate-*co*-3-hydroxyvalerate) (PHBV)

Tissue engineering is a popular field in medicine and the current market is estimated to be approximately \$23 million dollars, with a projected continuous growth in the coming years. Polyesters are one of the most competitive polymers for regenerative implantation surgeries, therapeutic cell culturing, and tissue repair. Of all the current commercial products, polyesters act as biologically passive supporting materials such as sutures, surgical mesh or netting, or drug-releasing vehicles. To address more advanced medical and regenerative applications, polyesters are modified to overcome issues such as low cell adhesion, hydrophobicity, and inflammatory side effects. Some of the most commonly used bio-based polyesters are poly(lactic acid) (PLA), poly(lactic-*co*-glycolic acid) (PLGA), poly-3-hydroxybutyrate (or poly-hydroxybutyric acid, PHB), poly(3-hydroxybutyrate-*co*-3-hydroxyvalerate) (PHBV). PLA is most commonly used in sutures due to its high tensile strength and elongation at break<sup>(45)</sup>.



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## 5. Conclusion

Plant seed oils are renewable alternatives to petrochemicals, but they cannot be used in their raw form except they are suitably modified. The unsaturated carbon-carbon double bonds in the fatty acid must be made to react with other monomers because the aim of the modification is to attach cross linkable functionalities to the fatty acid in order to have cross-linked thermoset material after curing. After modification and subsequent curing of the polymer, the final product should be a rigid thermoset material which cannot be reprocessed or melted. The level of unsaturation of the various fatty acids determines the type of polymerization that should be carried out. The in-depth study and the understanding of the fatty acids of the plant seed oils are paramount for their modification and further application in high technical area.

Vegetable oils are an abundantly available bioresource, which can be used at relatively lower cost for biopolymer synthesis. Because synthetic polymers create various problems, biobased polymers are expected to be used to partially reduce the high demand for traditional monomer-based polymers. The ample chances to modify triglyceride-based oils and their low-cost and easy availability have allowed these raw materials to be used fruitfully for the preparation of biopolymers. The reported properties of various types of biopolymers have already shown their novelty, and this has attracted investigators and researchers to work more on them. Various types of polymers, such as polyesters, PUs, polyamides, and vinyl polymers, can be produced with different types of polymerization reactions. These biobased polymers are important for various kinds of applications, such as adhesives, paints, printing inks, surface coatings, foams, and binders, for composite preparation. Investigations of these materials have found them to be comparable to traditional monomer-based ones in terms of their physicochemical, thermal, mechanical, anticorrosive, antimicrobial, and other related properties. Although a few drawbacks and challenges are associated with these vegetable-oil-based polymers, extensive studies on them may open a wide scope for potential use in advanced material sectors. Moreover, improvements in the processes and end properties of these materials with cost feasibility analysis are essential to draw attention from other possible scopes of vegetable oils, such as biodiesel and lubricant preparation, because they are considered potential competitors of biopolymers from the same source of raw materials.

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## Compliance with ethical standards

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### *Disclosure of conflict of interest*

All authors declare no conflict interest is exist.

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