



Review on the Manufacturing of Biodegradable Plastic Packaging Film from Root and Tuber Starches

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Abstract: Biodegradation of plastics occurs when microorganisms metabolize the plastics to either assailable compounds or to humus-like materials that are less harmful to the environment. They may be composed of either bio plastics, which are plastics whose components are derived from renewable raw materials or petroleum-based plastics which contain additives. Biodegradable plastic made from renewable resources is decreases dependence on petroleum and reduces the amount of waste material. Particular attention has been given in the recent years for the development of biodegradable polymers from renewable resources, especially for packaging and disposable applications to maintain sustainable development of economically and ecologically attractive technology, towards greener environment. Among these biopolymer, Starch is a cheap biopolymer that is totally biodegradable, ultimately up to carbon dioxide and water. Starch is an attractive biodegradable biopolymer because it is cheap with low density and can be blended with other polymers to produce composites with tailored properties. Starch can be found in various sources of cereals, root and tubers, such as rice, potatoes, corn, yam, wheat, cassava, and taro. The aim of this paper review was study on the manufacturing biodegradable plastic packaging film from root and tubers Starch. Root and tuber was used to produce starch based biodegradable plastic packaging film; like plastic packaging film from potatoes, sweet potatoes, enset, taro, cassava, and yam starch. Degradable plastics are grouped into photodegradable, oxidatively degradable, hydrolytically degradable and biodegradable plastics. The biodegradability of plastics depends upon their properties. The mechanism of biodegradation is affected by both the physical and chemical properties of plastics. The properties such as surface area, hydrophilic and hydrophobic character, the chemical structure, molecular weight, glass transition temperature, and melting point, elasticity, and crystal structure of polymers play important role in the biodegradation processes.

Keywords: Biodegradable, Bioplastic, Sweet Potatoes, Enset, Cassava, Taro, Yam, Polymer

1. Introduction

Petrochemical-based plastics such as polyethylene terephthalate (PET), polyvinylchloride (PVC), polyethylene (PE), polypropylene (PP), polystyrene (PS) and polyamide (PA) have been widely used as packaging materials due to their large availability and affordability. By virtue of its flexibility, petrochemical-based plastics were easily formed into sheets, shapes and structures. Moreover, the excellent mechanical performance such as tensile and tear strength, good barrier to oxygen and carbon dioxide and heat stability of these petrochemical-based plastics, increased their use for packaging materials. However, their use has been reduced currently because of their poor biodegradability which causes severe environmental problems [1]. Furthermore, chemicals

from these packaging materials migrated into food and contaminate the foodstuffs. The contamination at the certain level would be poisoning and risk for human health [2]. To overcome these drawbacks, plastics based on renewable resources which are biodegradable and non-toxic would be needed as a replacement for synthetic plastics.

Biodegradable plastics are plastics that will decompose in natural aerobic (composting) and anaerobic (landfill) environments. Biodegradation of plastics occurs when microorganisms metabolize the plastics to either assailable compounds or to humus-like materials that are less harmful to the environment. They may be composed of either bio plastics, which are plastics whose components are derived from renewable raw materials or petroleum-based plastics which contain additives [3].

Particular attention has been given in the recent years for the development of biodegradable polymers from renewable resources, especially for packaging and disposable applications to maintain sustainable development of economically and ecologically attractive technology, towards greener environment [4]. Among these biopolymer, Starch is a cheap biopolymer that is totally biodegradable, ultimately up to carbon dioxide and water.

Starch is an attractive biodegradable biopolymer because it is cheap with low density and can be blended with other polymers to produce composites with tailored properties. Starch $[(C_6H_{10}O_6)_n]$ is a carbohydrate polymer made up of many monosaccharide units joined by glycosidic bonds, thus it is a polysaccharide. Starch consists of linear amylose (20-25%) and branched amylopectin (75-80%) at ratios that vary with the sources [5]. Corn starch, for example, contains 28 percent of amylose while it is only 17 percent in cassava. Taro starch contains amylose ranging from 22.8 to 35.7 percent depending on its variety [6]. Starch can be found in various sources of cereals, root and tubers, such as rice, potatoes, corn, yam, wheat, cassava, and taro. The thermo mechanical, film formation and physical properties bio plastics made of starch depend on the ratio of amylose to amylopectin in starch [7]. Amylose is a linear molecule with a few branches, whereas amylopectin is a highly branched molecule. Therefore, amylose content contributes to film strength and branched structure of amylopectin generally leads to film with low mechanical properties [8]. To increase film flexibility, plasticizers are used due to their ability to reduce internal hydrogen bonding between polymer chains while increasing molecular space. Starch-based BPs can be produced by blending or mixing them with synthetic polymers. By varying the synthetic blend component and its miscibility with starch, the morphology and hence the properties can be regulated easily and efficiently. Blends containing thermoplastic starch (destructured starch that is noncrystalline, produced by the application of heat and work) may be blended or grafted with biodegradable polyesters [such as polycaprolactone (PCL)] to increase flexibility and resistance to moisture. These materials are mainly formed into films and sheets [9].

In food packaging section, starch based plastic is most considered and widely accepted. Plastic that contained starch did not have a negative effect on quality of food or other packed materials [10]. Also, starch based plastic did not have a negative effect on the environment and also reduced the greenhouse effect [11]. Synthetic plastic takes a long time to degrade in nature. The use of starch as a biodegradable agent accelerated the time of degradation in the environment.

Objective of the Review

The aim of the paper review was;

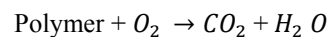
- To review the Biodegradable plastic packaging film from Root and Tubers Starch,
- To review Uses of Starch for manufacturing Biodegradable plastic packaging film, and
- To review factors affecting the Biodegradability of plastic packaging film from Root ant Tubers Starch.

2. Leterature Review

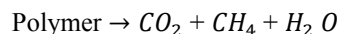
Non-biodegradable petroleum-based commodity polymers, such as polyethylene (PE), polypropylene (PP), polystyrene (PS) and poly terephthalate (PET), have caused serious environmental concerns globally [12]. Although huge efforts have been made to recycle commodity plastics and reduce the landfill, it is still not cost-effective. Therefore, alternatives are sought for, which can be produced from renewable resources and can degrade in a natural environment without generating harmful and toxic residues [13]. Decades of studies have led to the discovery of many biodegradable polymers (i.e. plastic films) with distinctive properties, such as polysaccharides (i.e. starch), proteins and polyesters [13, 14].

According to ASTM standard D-5488-94d and European norm EN 13432, “biodegradable” means “capable of undergoing decomposition into carbon dioxide, methane, water, inorganic compounds, and biomass”. The predominant mechanism is the enzymatic action of microorganisms, which can be measured by standard tests over a specific period of time, reflecting available disposal conditions. There are different media (liquid, inert, or compost medium) to analyze biodegradability. Biodegradation is the degradation of an organic material caused by biological activity (biotic degradation), mainly microorganisms’ enzymatic action. The end products are CO_2 , new biomass, and water (in the presence of oxygen, i.e. aerobic conditions) or methane (in the absence of oxygen, i.e., anaerobic conditions), as defined in the European Standard EN 13432-2000 [15].

Aerobic biodegradation of Bioplastic (such as composting)



Anaerobic biodegradation of Bioplastic (such as anaerobic digestion and landfill):



Biodegradability depends strongly on the environmental conditions: temperature, presence of microorganisms, and availability of oxygen and water [16, 17].

In recent decades, the plastic industry and the academic community have been together looking for new raw materials to replace the petrochemical polymers, which are produced from nonrenewable resources [15]. Biodegradable plastic made from renewable resources decreases dependence on petroleum and reduces the amount of waste material, while still yielding a product that provides similar benefits of traditional plastics [18]. The major difference between synthetic polymers and natural polymers is the presence of oxygen and nitrogen in the natural polymers. The oxygen and nitrogen in the polymer structure permit the polymer to biodegrade [19]. Bio-based polymers have been shown to be a viable alternative to replace these fossil sources while also having environmental advantages, such as decreasing toxic emissions [20].

Biodegradable plastic films can form the basis for environmentally preferable, sustainable alternative to current material exclusively based on petroleum feed stocks.

Biopolymers are generally capable of being utilized by living matter (biodegraded), and so can be disposed in safe condition. The use of biopolymers within this field appears as an excellent alternative for reducing current environmental problems [21].

2.1. Methods of Measuring Biodegradation

In nature, different materials biodegrade at different rates, to be able to work effectively, most microorganisms that assist the biodegradation need light, water and oxygen. Temperature is also an important factor in determining the rate of biodegradation. This is because microorganisms tend to reproduce faster in warmer conditions. Many products that are biodegradable in soil – such as tree trimmings, food wastes and paper – will not biodegrade when placed in landfills, because the artificial landfill environment lacks the light, water and bacterial activity required for the decay process to begin. Biodegradation can be measured in a number of ways. Scientists often use respirometry tests for aerobic microbes. First one places a solid waste sample in a container with microorganisms and soil and then aerate the mixture. Over the course of several days, microorganisms digest the sample bit by bit and produce carbon dioxide – the resulting amount of CO_2 serves as an indicator of degradation. Biodegradation can also be measured by anaerobic microbes and the amount of methane or alloy that they are able to produce [3].

2.2. Biodegradability of Plastics Materials

The American Society for Testing of Materials (ASTM) and the International Standards Organization (ISO) define degradable plastics as those which undergo a significant change in chemical structure under specific environmental conditions [22]. These changes result in a loss of physical and mechanical properties. Usually, the adherence of microorganisms on the surface of plastics followed by the occupation of the exposed surface is the main mechanisms taking place in the microbial degradation of plastics.

Degradable plastics are grouped by the American society for Testing and Materials [22].

(a) Photodegradable plastics – a degradable plastic in which the degradation results from the action of natural daylight;

(b) Oxidatively degradable plastics – a degradable plastic in which the degradation results from oxidation;

(c) Hydrolytically degradable plastics – a degradable plastic in which the degradation results from hydrolysis; and

(d) Biodegradable plastics - a degradable plastic in which the degradation results from the action of naturally occurring microorganisms such as bacteria, fungi and algae.

As the plastics defined in categories (a), (b) and (c) require additional inputs, such as light (UV) or oxygen for degradation, the biodegradable plastics (d) offer the only products which are “naturally” degradable. There has been a widespread interest in films made from renewable and natural polymers which can degrade naturally and more

rapidly than the petroleum-based plastics [23].

Starch undergoes complete degradation in a natural environment by enzymatic hydrolysis into glucose which is then metabolized into water and carbon dioxide, therefore, the degradation of starch and its composites start from the outside into the inside of the material. Starch mixed with other polymers alters the rate of degradation of such material [24].

The enzymatic degradation of plastics by hydrolysis occurs by a two-step process. In the first step, the enzyme binds to the polymer substrate and then catalyses a hydrolytic cleavage of the polymer. Polymers get degraded into low molecular weight oligomers, dimers and monomers and lastly to CO_2 and H_2O . The degradation potential of various microorganisms towards a polymer is usually assessed by using a clear zone method with agar plates. Agar plates having blended polymers are injected with microorganisms. These polymer degrading microorganisms excrete extracellular enzymes that diffuse through the agar and then degrade the polymer into water soluble substances. Using this technique, it was observed that poly hydroxybutyrate (PHB), polypropiolactone (PPL) and Polycaprolactone (PCL) degraders are extensively dispersed in diverse environments [25]. Most of the strains which are able to degrade PHB belong to different taxonomy such as Gram-positive and Gram-negative bacteria, *Streptomyces* and fungi [26]. About 39 bacterial strains of the classes *Firmicutes* and *Proteobacteria* have been reported to degrade PHB, PCL, and PBS, but not PLA [27]. Only a few microorganisms have been isolated and identified which can degrade PLA. In the different ecosystems the populations of aliphatic polymer-degrading microorganisms have been found to be in the following order: PHB = PCL > PBS > PLA [12, 25].

2.3. Biodegradable Film Forming Materials

Film forming materials, such as starches, proteins and polyols, are used for different purposes in a biomaterial and/or edible film preparation process. Biopolymers like starches and proteins create the basic network structure of the film. However, films prepared from biopolymers are often too fragile to stand handling, e.g., bending or stretching. Thus, they have to be plasticized using low molecular weight substances, such as polyols, which decrease interactions between the biopolymer chains. Due to plasticization better handling properties may be obtained whereas other properties, such as water sorption, gas permeability and mechanical properties may weaken.

2.4. Plasticizers

Plasticizers are an important class of low molecular weight non-volatile compounds that are widely used in polymer industries as additives [28]. The most frequently used plasticizers in starch-based films are polyols, such as sorbitol and glycerol. The primary roles of such substances are to improve the flexibility and process ability of polymers by lowering the second order transition temperature, the glass transition temperature (T_g). The council of the IUPAC (International Union of Pure and Applied Chemistry) defined a

plasticizer as “a substance or material incorporated in a material (usually a plastic or elastomer) to increase its flexibility, workability, or distensibility”. These substances reduce the tension of deformation, hardness, density, viscosity and electrostatic charge of a polymer, at the same time as increasing the polymer chain flexibility, resistance to fracture and dielectric constant [29]. Other properties are also affected, such as degree of crystallinity, optical clarity, electric conductivity, fire behavior and resistance to biological degradation, amongst other physical properties [30].

2.5. Starch

Starch is the most abundant storage reserve carbohydrate in plants. It is found in many different plant organs, including seeds, fruits, tubers and roots, where it is used as a source of energy during periods of dormancy and regrowth [31]. A range of native starches from different sources with highly different functionalities are already on the market. Each starch is named according to its plant source, e.g. potato starch, cassava starch, taro starch, *enset* starch, yam starch, maize starch and rice starch. These groups are distinctly different from each other with respect to chemical composition and physical properties [32].

Structure and Properties of Starch

Starch is made up of two polymers of D-glucose: amylose, an essentially unbranched α [1 \rightarrow 4] linked glucan, and amylopectin, which has chains of α [1 \rightarrow 4] linked glucoses arranged in a highly branched structure with α [1 \rightarrow 6] branching links. Amylose and amylopectin make up 98–99% of the dry weight of native granules, with the remainder comprising small amounts of lipids, minerals, and phosphorus in the form of phosphates esterified to glucose hydroxyls. Starch granules range in size from 1 to 100 μm diameters and shape of polygonal, spherical, lenticular, and can vary greatly in content, structure and organization of the amylose and amylopectin molecules, the branching architecture of amylopectin, and the degree of crystallinity [33].

There are a lot of hydroxyl groups on starch chains, two secondary hydroxyl groups at C-2 and C-3 of each glucose residue, as well as one primary hydroxyl group at C-6 when it is not linked. Evidently, starch is hydrophilic. The available hydroxyl groups on the starch chains potentially exhibit reactivity specific for alcohols. In other words, they can be oxidized and reduced, and may participate in the formation of hydrogen bonds, ethers and esters [34]. Starch has different proportions of amylose and amylopectin ranging from about 10–20% amylose and 80–90% amylopectin depending on the source [35]. Amylose is soluble in water and forms a helical structure. Starch occurs naturally as discrete granules since the short branched amylopectin chains are able to form helical structures which crystallize. Starch granules exhibit hydrophilic properties and strong inter-molecular association via hydrogen bonding formed by the hydroxyl groups on the granule surface. Owing to its hydrophilicity, the internal interaction and morphology of starch will be readily changed. By water molecules, and thereby its glass transition temperature (T_g), the dimension and mechanical properties

depend on the water content. T_g of native starch can be as low as 60 to 80°C when the weight fraction of water is in the range 0.12 to 0.14, which allows starch to be successfully injection moulded to obtain thermoplastic starch polymers in the presence of water [36]. On the other hand, the hydrophilicity of starch can be used to improve the degradation rate of some degradable hydrophobic polymers. Starch is totally biodegradable in a wide variety of environments. It can be hydrolyzed into glucose by microorganism or enzymes, and then metabolized into carbon dioxide and water [37]. Films developed from starch are described as isotropic, odorless, colorless, non-toxic and biologically degradable [38].

2.6. Starch Based Biodegradable Plastic Packaging Film

Bioplastics are sustainable, largely biodegradable and biocompatible. A simple bioplastic is formed with the following equation:

$$\text{Biopolymer (s) + plasticizer (s) + other additive (s) = BIOPLASTIC}$$

A bioplastic is formed from starch, gelatin/agar, sorbitol, glycerol (glycerin). These ingredients are heated to just below boiling (95°C) in a hot plate and later dried in an oven [18].

2.6.1. Plastic Packaging Film from Sweet Potato (*Ipomoea Batatas*) Starch

Sweet potato contains a 50–80% starch on a dry basis and sweet potato starch comprises 70–80% of highly branched amylopectin and 20–30% of linear and slightly branched amylose [39]. In addition, sweet potato starch has comparable properties with ordinary potato starch which is rich in dietary fiber, minerals, vitamins and antioxidants, such as phenolic acids, anthocyanins, tocopherol, β -carotene and ascorbic acid which could be migrated into food in case that sweet potato starch-based plastics are used for food packaging and would enhance the nutritional value of the food package [40].

The biodegradable films made of Sweet potato starch were prepared by mixing starch with glycerol using different starch: glycerol w/w ratio (2.5: 1, 2.75: 1, 3: 1 and 3.5: 1). The mixtures were heated in an oven at 50°C for 1.5 h and were poured into iron molds of 20×20 cm. The samples were pressed by using compression molding at 135°C for 10 min under a load of 50 kg cm^2 to form bio plastic sheets [22]. The change in starch: glycerol ratio would alter the characteristics and properties of Bioplastic which allows sweet potato starch-based bio plastics to be used for food packaging application. Therefore, bio plastics with high starch: glycerol ratio exhibited faster degradation. The Plastic packaging film from Sweet potato Starch prepared is exhibited the signs of degradation after 7 days.

2.6.2. Plastic Packaging Film from Taro (*Colocasia Esculenta*) Starch

Taro tubers has potent as a source of carbohydrates about 70–80 which consists of 5.55% of amylose and 74.45% of amylopectin with a yield of 28.7%. Its high starch causes taro potential as a biodegradable plastic packaging film material

[41]. A biodegradable film made of taro starch and chitosan plasticized by castor oil was created through a casting solvent method. The film was prepared by solvent evaporation where taro starch (TS) and chitosan (CH) were initially weighed and later dissolved in 50 mL of 2 percent acetic acid while continuously stirred for 5 h at 70°C. Next, castor oil was added, and the stirring continued for 45 minutes at 70°C [6]. The mixture was poured in a petri dish and left at room temperature for one hour prior to solvent evaporation at 75°C for 6-7 h. The film was then removed from the oven and cooled at room temperature. The higher proportion of chitosan in the polymer matrix succeeded in increasing the tensile strength and thermal stability of the film and the addition of chitosan into taro starch samples are reducing the water uptake of the film. But the film with a balanced ratio of taro and chitosan starch had excellent water resistance; its absorption of water is the lowest of all composition [22].

2.6.3. Plastic Packaging Film from Cassava (*Manihot Esculenta*) Starch

Cassava starch was used for preparation of biodegradable plastic film. The cassava starch was first tested for moisture content using infra-red moisture meter and it was found to contain 12% moisture. This was done in order to ensure that the starch contains not more than 13% moisture. A mixture of 1 kg powdered cassava starch, 2 kg polyvinyl alcohol liquid, 100 g talc powder, and 100g urea was prepared. The resulting mixture was added to 400 ml of glycerin. The whole mixture was stirred to yield a semi dry powder. Thereafter, the mixture was then extruded with a Blown film extruder to produce a biodegradable film, which can either be used directly or modified/processed further for use. The film was produced under the following conditions: Zone 1 temperature of 190°C, Zone 2 Temperature of 220°C, Melt Temperature of 200°C, Film die diameter of 300µm, and Extruder speed of 60rpm [23]. And also [42] have reported the biodegradable plastics from cassava starch using a concentration of 6% with the addition of a mixture of plasticizers glycerol and sorbitol in a ratio of 100: 0 as much as 1%. Biodegradable plastic is dried at 60°C for 4 hours and produce characteristics of the water content of 3.98%, elongation at break of 18.75%, tensile strength of 930 M Pa and a Young's modulus of 50 M Pa.

2.6.4. Plastic Packaging Film from Potato (*Solanum Tuberosum L.*) Starch

Potato starch is one of the suitable resources for film formation and has a potential use for packaging [43]. The Starch based Biodegradable plastic packaging films from potato starch were prepared by casting technique using a film-forming solution containing potato starch. Glycerol was used as a plasticizer in the filmogenic solution to increase the flexibility and plasticity of the film. The mixture of dry starch, water and glycerol was taken in a beaker. Distilled water was added to solution as it acts as the plasticizer and it decreases the brittleness of plastic films. So water is used to make the solution of starch. Then required amount of citric acid was added to the solution. In packaging films, citric acid

is added to increase the antimicrobial, plasticizing and dispersing effect in biodegradable/edible films and to improve the mechanical properties and water vapor permeability [44]. The entire mixture was filtered with the help of muslin cloth. The mixture was mixed with the help of glass rod on hot plate at 40°C for 5 mins. The mixture was kept in water bath at 70°C temperature for 10 minutes. A cast was prepared and the entire solution was poured on the cast and was left for drying at room temp for 48 hrs. After drying the films were peeled off and were kept in poly bags away from moisture [22].

2.6.5. Plastic Packaging Film from Enset (*Enset Ventricosum*) Starch

Enset starch was used for preparation of biodegradable plastic film and the *Enset* starch-based packaging films were prepared by the procedure adapted from the method described by [45]. Casting was used because it is the commonly used technique to prepare films on a laboratory scale. Five grams of Enset starch was mixed with distilled water at room temperature (25 °C). This suspension was then transferred to a water bath set at 75-90°C. For 2-5 minutes this suspension was stirred continuously on water bath and 15, 20 and 25% glycerol added on it and stirred manually until became gelatinized (5-10 minutes) [46]. The mixture was stirred for homogeneity and to make the gelatin. Then, it was poured into petri dishes to keep its uniform thickness [47] and petri dishes placed into an oven at 35, 45, and 55°C until the films dry. Subsequently, the petri dishes removed from the oven. The measurement of the adequacy of the drying process of the film has been determined when it is easily peeled off from the petri dish without any left residues [48]. According to [46] reported that, the *enset* starch has capability of being an edible packaging flexible film.

2.6.6. Plastic Packaging Film from Yam (*Dioscorea alata*) Starch

Yam starch is one alteration for polymeric carbohydrate composed of anhydroglucose units. It is not a uniform material and most starch contains two types of glucose polymers: a linear chain molecule termed amylose and a branched polymer of glucose termed amylopectin [49]. Yam starch (*D. alata*) contains about 24-26% amylose; the ratio of amylose to amylopectin content is 0.32, and this is important for film production because amylose is responsible for the film-forming capacity of starches [50].

The biodegradable yam starch based films were prepared by casting; yam starch (dry basis) and glycerol were directly mixed with distilled water to make batches with a total weight of 500 g. The filmogenic solutions were transferred quantitatively to the cup of a Brabender Viscograph, and its where heated from 30 to 80°C at a constant heating rate (2°C/min) and maintained at 80°C for 10 min, with regular shaking (75 rpm). Gelatinized suspensions were immediately poured on rectangular acrylic plates (20×20 cm). For each experiment, the quantity of starch suspension poured onto the plate was calculated to obtain a constant weight of dried matter of approximately 12.25 mg/ cm². The starch

suspensions were dried (45°C) in a ventilated oven (about 4 h). The result was translucent films, which can be easily removed from the plate [51]. The films were equilibrated at room temperature and a relative humidity (RH) of 70% for 48 h before being tested [52, 53]. The research showed that the appearance of yam starch film for most of the formulations was transparent, smooth, and glossy. Yam starch film as biofilms could be applied and developed in qualities, and with the advantage of biodegradability [51].

2.7. Factors Affecting the Biodegradability of Polymers

The biodegradability of plastics depends upon their properties. The mechanism of biodegradation is affected by both the physical and chemical properties of plastics. The properties such as surface area, hydrophilic and hydrophobic character, the chemical structure, molecular weight, glass transition temperature, and melting point, elasticity and crystal structure of polymers play important role in the biodegradation processes. Since molecular weight determines many physical properties of the polymers so it also plays an important role in determining their biodegradability. In general, biodegradability the polymer decreases with increasing the molecular weight of the polymer. Furthermore, the morphology of polymers also greatly affects their rates of biodegradation. As enzymes mostly attack the amorphous areas of a polymer hence the degree of crystallinity is also a key factor affecting biodegradability. This is because the molecules in the amorphous part of polymer are loosely packed so make it more prone to degradation. However, the crystalline part of the polymer is more resistant than the amorphous region due to closer packing of the molecules. The studies have shown that the rate of degradation of poly lactic acid (PLA) decreases with an increase in crystallinity of the polymer [54]. The melting temperature (T_m) of polymers also has a large effect on the enzymatic degradation of polymers. The higher the melting point of the polymer, the lower is the biodegradation of the polymer [54].

3. Conclusion

Non-biodegradable petroleum-based commodity polymers have caused serious environmental concerns globally. Although huge efforts have been made to recycle commodity plastics and reduce the landfill, it is still not cost-effective. Therefore, alternatives are sought for, which can be produced from renewable resources and can degrade in a natural environment without generating harmful and toxic residues. The use of Starch based biodegradable plastics is however, a sure solution to the problems of plastic waste accumulation as it is economically viable and not harmful to our environment as the waste can readily decompose in the soil and the decomposed waste can be used as manure for growing crops, starchy crops inclusive which are raw materials for bio-plastic production. The future of starch based biodegradable plastics shows great potential. Biodegradable plastics will be used all depends on how strongly society embraces and believes in environmental

preservation. Further research and development in the Starch based biodegradable plastics is the need of the hour because of human responsibility towards environment. That is the main driving force implementing the tremendous potential of biopolymers in future.

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