Current Trends in Technology and Science
ISSN : 2279-0535. Volume : 3, Issue : 2

Recent trends of Biodegradable polymer: Biodegradable films for Food Packaging and application of Nanotechnology in Biodegradable Food Packaging

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Abstract — Most of today synthetic polymer are produced and they have undesirable influence on the environment and cause problem with waste deposition and utilization. The one of the approaches to solving these problem is the development of biodegradable polymer. This review provides information on performance of biodegradable polymer, focusing on food packaging. It gives an overview of classification of biodegradable polymer and mainly concentrated on Biodegradable polymers from biomass products. The application of nano technology in food packaging expand the use of edible and biodegradable films that reduce the packaging waste associated with processed foods this supports the preservation of fresh foods by extending their shelf life.

Keyword — Biodegradable, packaging, polymer, nanotechnology.

1. INTRODUCTION

In the past 20 years, the production and the use of plastics in the world have been enormously increased [1]. Most of today's synthetic polymers are produced from petrochemicals and are not biodegradable. Persistent polymers generate significant sources of environmental pollution, harming wildlife when they are dispersed in nature [2].

Worldwide statistic show that 43 percent of marine mammal species, 86 percent of sea turtle species, and 44 percent of sea bird species are susceptible to ingesting marine plastic debris [3]. Plastic production has increased from 0.5 to 260 million tonnes per year since, 1950. 40% of plastics produced every year is discarded into Landfill. Every year, more than 500 billion plastic bags are distributed, and less than 3% bags are recycled. They are typically made of polyethylene and can take up to 1,000 years to degrade in landfills that emit harmful greenhouse gases [4].The solution to the problem may be biodegradable polymers. The term ''biodegradable'' materials is used to describe those materials which can be degraded by the enzymatic action of living organisms, such as bacteria, yeasts, fungi and the ultimate end products of the degradation process, these being CO_2, H_2O and biomass under aerobic conditions and hydrocarbons, methane and biomass under anaerobic conditions [5].

In the process of biodegradation the firstly the long polymer molecules are reduced to shorter and shorter lengths and undergo oxidation (oxygen groups attach themselves to the polymer molecules). This process is triggered by heat (elevated temperatures found in landfills), UV light (a component of sunlight) and mechanical stress (e.g. wind or compaction in a landfill). Oxidation causes the molecules to become hydrophilic (water attracting) and small enough to be ingestible by microorganisms, setting the stage for biodegradation to begin. Biodegradation occurs in the presence of moisture and microorganisms typically found in the environment. The plastic material is completely broken down into the residual products of the biodegradation process (Fig, 1). As microorganisms consume the degraded plastic, carbon dioxide, water, and biomass are produced and returned to nature by way of the biocycle [6].

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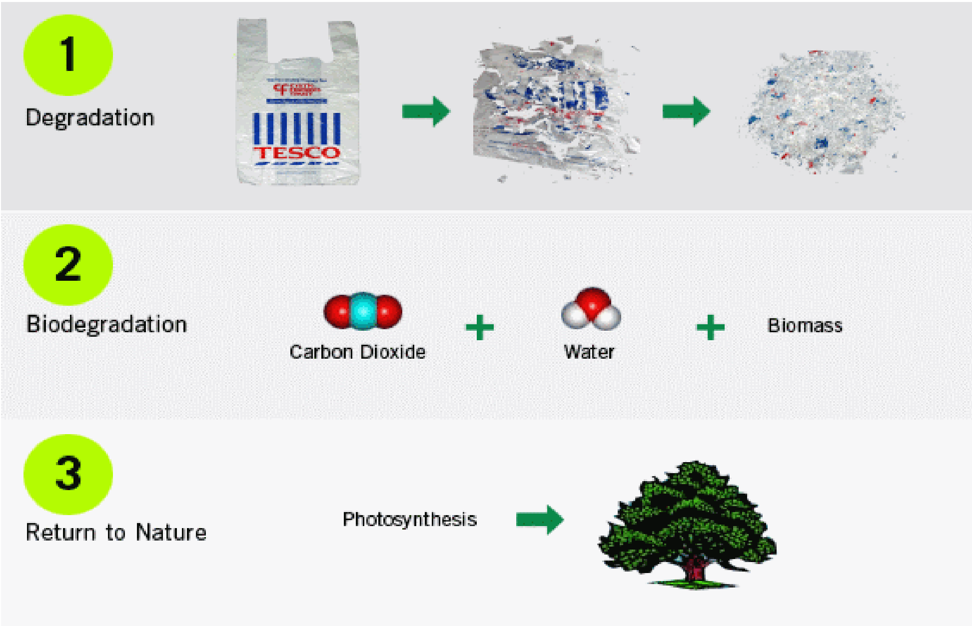

Fig, 1; Process of biodegradation

2. Biodegradable Polymer Films For Food Packaging

Food packaging is becoming increasingly important in the food industry, where advances in functionality such as convenience and portioning are gaining more attention. Furthermore, there is also an increased awareness on sustainability, which can in general be achieved on different levels. On the level of raw materials, use of recycled materials or use of renewable resources are two strategies to reduce CO_2 emissions and the dependency on fossil resources. The production process is another level where adjustments, e.g. toward a more energy efficient process, can be made. A final level where efforts can be done to increase sustainability is waste management. Next to reuse and recycling of used materials, production of packaging which is biodegradable and/or compostable contributes to reducing the municipal solid waste problem [7] [8]. In the last decade, there has been an increased interest from the food, packaging and distribution industry toward the development and application of bioplastics for food packaging [9].

Biodegradable products are mainly produced from biopolymers. Biopolymers are used in packaging materials (trash bags, wrappings, loose-fill foam, food containers, film wrapping, laminated paper), disposable nonwovens (engineered fabrics) and hygiene products (diaper back sheets, cotton swabs), consumer goods (fast-food tableware, containers, razor handles, toys), and agricultural tools (mulch films, planters) [10]. Biodegradable polymer represent a growing field [11]. A vast number of biodegradable polymers (e.g. cellulose, chitin, starch, polyhydroxyalkanoates, polylactide, polycaprolactone, collagen and other polypeptide) have been synthesized or are formed in natural environment during the growth cycles of organisms. Some microorganisms and enzymes capable of degrading such polymers have been identified [12]. Biodegradable polymers are classified according to their synthesis process (Fig, 2): polymers from biomass such as agro-polymers from agro-resources; polymers obtained by microbial production; polymers conventionally and chemically synthesized from monomers obtained from agro-resources; and polymers obtained from fossil resources [2].

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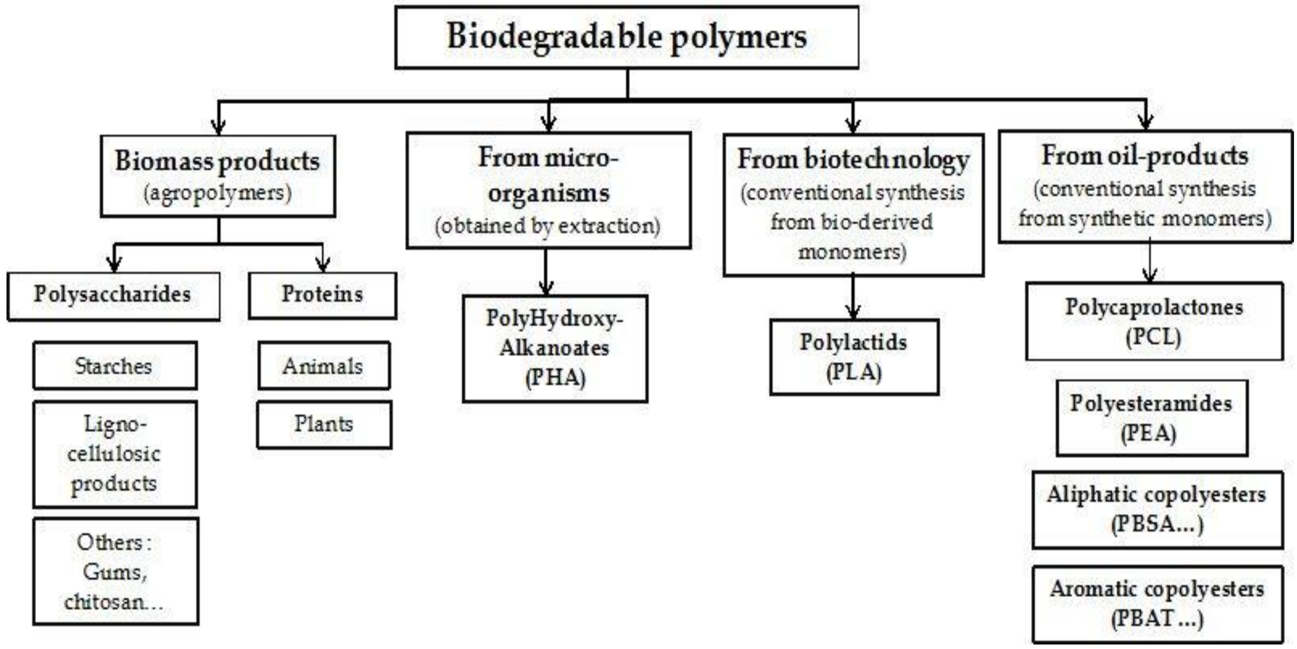

Fig.2. Classification of biodegradable polymer

2.1 Biodegradable polymers from biomass products.

2.1.1 Starch

Starch is a major plant storage form of glucose. It consists of two component: amylose, in which the glucose unit are 1,4-α-D- linked together in straight chains (Fig, 3), and amylopectin , in which the glucose chain are highly branched [13] [14]. Starch has different proportion of amylase and amylopectin ranging from 10-20% amylase and 80-90% amylopectin depending on the sucrose [15]. Starch can be oxidized and reduced, and may participated in the formation of hydrogen bonds, ethers and esters [16].The hydrophilicity of starch can be used to improve the degradation rate of some degradable hydrophobic polymers [17].

Principally, there are three ways how starch can be used for biodegradable polymer production. The first one is the preparation of starch composition with other plastics with a low amount of starch to enhance the biodegradability of traditional oil-based polymer materials.The second way of starch application is the preparation of starch composit with starch content being more than half by mass and third way of starch biodegradable polymers preparation uses the extrusion processing of mixtures of granular starch [18].

2.1.2 Celluose

Cellulose is the most widely spread natural polymer and is derived by a delignification from wood pulp or cotton linters. It is a biodegradable polysaccharide which can be dissolved in a mixture of sodium hydroxide and carbon disulphide to obtain cellulose xanthate and then recast into an acid solution (sulfuric acid) to make a cellophane film [19] [20] [21]. Alternatively, cellulose derivatives can be produced by derivatization of cellulose from the solvated state, via esterification or etherification of, hydroxyl groups. Especially these cellulose derivatives were the subject of recent research. Cellulose esters like cellulose

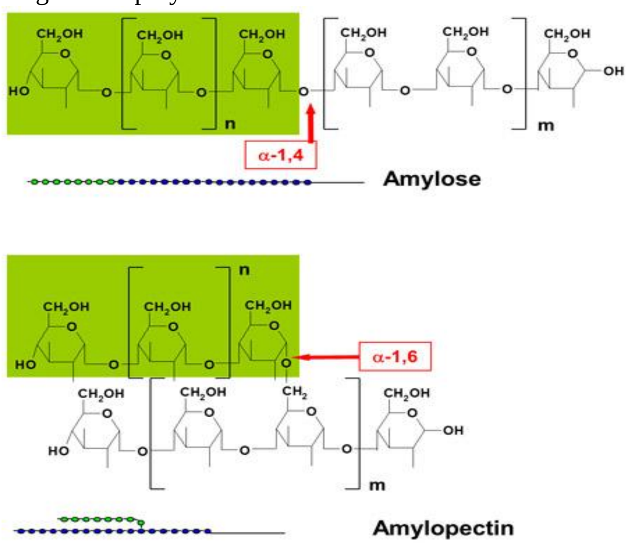

Fig. 3; Structure of Amylose and Amylopectin

(di)acetate and cellulose (tri)acetate need addition of additives to produce thermoplastic materials. Most of them can be processed by injection molding or extrusion [21] [21] [23].

2.1.3 Other materials

2.1.3.1 Pectin

Pectin is a linear macromolecule constituted of α(1-4)-linked D-galacturonic acid (Fig. 4). This monomer unit could be partially replaced by α(1-2)-linked L-rhamnose leading to a new structure named rhamnogalacturonan I. A third pectin structural type is rhamnogalacturonan II, which is a less frequent, but complex and highly branched polysaccharide [24]. In nature, around 80 % of the galacturonic acid carboxyl groups are esterified with methanol. This proportion depends on the extraction conditions. Since the ratio of esterified/non esterified galacturonic acid determines the behavior of pectin in food applications, pectins are classified as high or low ester pectins [25].

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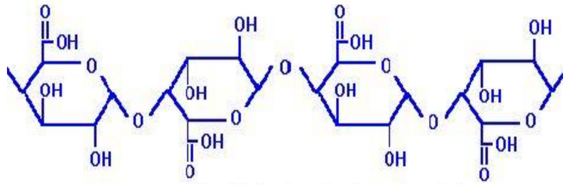

Fig. 4; Pectin (Polygalacturonic acid)

2.1.3.2 Citin and chitosan

Chitin is the second most abundant agro-polymer produced in nature after cellulose. It appears in nature as ordered crystalline microfibrils forming structural components in the exoskeleton of arthropods or in the cell walls of fungi and yeasts [26]. It is biodegradable, nontoxic and readily biocompactible [27]. Usually chitin is extracted from crab crumb. During a pre-treatment phase dilute solution of sodium hydroxide (pH 13.5) dissolved any remaining flesh and prevents further microbial activity or shell degradation. The crushed shell are conveyed into reactor, where they are treated with hydrochloric acid to gasify the materials.

In the third stage of process, to liquefy proteins and produce chitin. the material is washed before entering another NaOH solution with a slightly elevated temperature on a dry mass basis there is 12% yield in the process of extracting chitin from crab chum [18]. Chitosan is produced from chitin (Fig. 5). It is washed and put through boiling lye to remove acetate from the molecule. After hydrolysis, the resulting chitosan is washed, dried, ground, weighed and packed for sale [18][26].

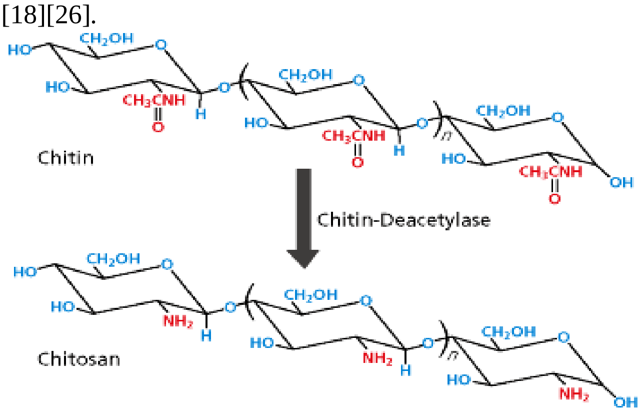

Fig. 5; Chitin and Chitosan

2.1.3.3 Proteins

A certain number of protein have received much attention as biodegradable polymer but few have led to actual industrial scale up due to the high production cost and the low product performance. In terms of potential sources, soy protein, corn protein (zein) and wheat proteins (gluten) are among the main plant proteins. Casein, collagen protein or gelatin, and keratin are important animal proteins. Lactate dehydrogenase, chymotrypsin, and fumarase constitute the main bacterial proteins [2] [28].

2.2 ADVANTAGE AND LIMITATIONS OF BIODEGRADABLE POLYMER

Films and coatings prepared from biodegradable materials are increasingly being used in the food packaging industry [5]. The use of protective coatings and suitable packaging by the food industry has become a topic of great interest because of their potentiality for increasing the shelf life of many food products. By means of the correct selection of materials and packaging technologies, it is possible to keep the product quality and freshness during the time required for its commercialization and consumption circumstances [28]. In the food packaging sector, starch-based material has received great attention owing to its biodegradability and low cost unfortunately, the starch presents some drawbacks, such as the strong hydrophilic behavior (poor moisture barrier) and poorer mechanical properties than the conventional non-biodegradable plastic film used in food packaging industry [1].

Protein base material has desirable film forming and barrier properties, which compare well to petro based products [29]. Recent report pointed out films produced from soy protein isolate were found to be high film forming property, low cost and excellent oxygen barrier property but these protein film exhibit poor mechanical property and water barrier property [30] [31] [32]. Way protein and caseinates are milk proteins, which have also been extensively studied owing to their excellent nutritional value and their numerous functional properties which are important for the formation of edible films [33]. Edible films based on whey protein were reported to be flavourless, tasteless, flexible [34] and has desirable film forming and barrier properties, which compared well to petrobased products [33]. However the low tensile strength and high water vapor permeability [35] [41].

Unfortunately, so for the use of biodegradable films for food packaging has been strongly limited because of the poor barrier properties and weak mechanical properties shown by natural polymers. For this reason natural polymers were frequently blended with other synthetic polymers or, less frequently, chemically modified with the aim of extending their applications in more special or severe circumstances. The application of nano-composites promises to expand the use of edible and biodegradable films that reduce the packaging waste associated with processed foods this supports the preservation of fresh foods by extending their shelf life [28] [29] [30] [41].

3. NANOTECHNOLOGY IN BIODEGRADABLE POLYMER

The problems associated with biodegradable polymers are threefold: performance, processing and low cost, although these factors are somewhat interrelated, problems due to performance and processing are common to all biodegradable polymers in spite of their origin [36]. In particular, brittleness, low heat distortion temperature, high gas and vapour permeability, poor resistance to protracted processing operations have strongly limited their application. The application of nanotechnology to these polymers may open new possibilities for improving not only the properties but also the same time the cost-price-efficiency [28].

Nanotechnology is generally defined as the creation and utilization of structures with at least one dimension in the

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nanometer length scale (10^{-9}m). These structures are called nanocomposites and could exhibit modifications in the properties of the materials or create novel properties and phenomena to the materials. To achieve these modifications, a good interaction between the polymer matrix (continuous phase) and the nanofiller (discontinuous phase) is desired [9]. When bioplastics are mixed with nanoclay particles, the resulting nonocomposites exhibit improved barrier properties compared with the pure bioplastics, and after their useful life can be composted and returned to the soil. Other nanomaterials can be utilized including nanoparticles, nanofibers and nanowhiskers [28] [37] [41]. The clay has a unique morphology that contains one dimension on the nanoscale. Nanoclay-composites have been developed for potential use in a variety of food packaging applications and some products are already available for the consumer. The montmorillonite is hydrated alumina-silicatelayered clay. This special clay has a structure that limits the permeation of gas due to the large aspect ratio and tutourity [38].

To obtain the polymer composite improvements a small percentage of clay can be included in the polymer matrix. This process is called solid layer dispersion in polymers and involves two major steps; intercalation and exfoliation shown in Fig. 6. [28]. In exfoliation, the clay particles are released from this system and are dispersed in the matrix polymer with no apparent particle interactions. The result is layers of nanoclay woven into the polymers structural matrix. Introduction of the dispersed clay layers into the polymer matrix structure has been shown to greatly improve the overall mechanical strength and barrier properties of the material, making the use of nanocomposites films industrially practicable [28].

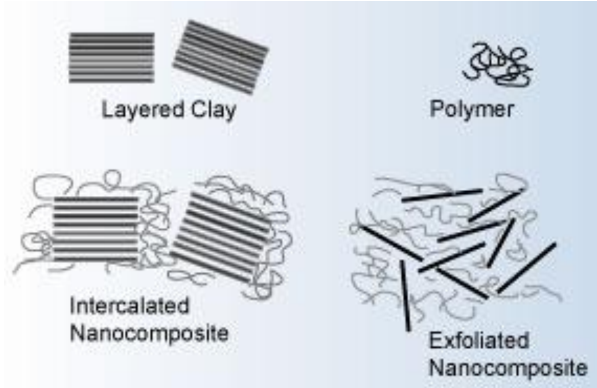

Fig. 6; Clay delamination/dispersion

Many biopolymers such as chitosan, cellulose, collagen Zein have been derived synthesized as nanofibres from various biopolymers using the electrospinning technique. In some cases these have superior properties to the traditionally cast polymer, including increasing heat resistence [39].

Polymer nanocomposites are constructed by dispersing a filler material into nanoparticles that form flat platelets. These platelets are then distributed into a polymer matrix creating multiple parallel layers which force gases to flow through the polymer in a torturous path, forming complex. barriers to gases and water vapor, (Fig. 7). As more tortuosity is present in a polymer structure, higher barrier properties will result

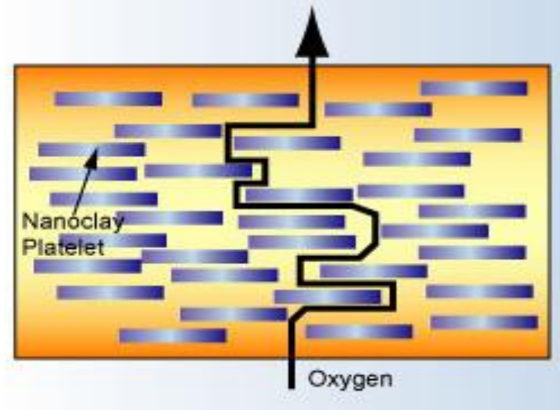

Fig. 7; Nanocomposit oxygen barrier property

Nanoparticles allow for much lower loading levels than traditional fillers to achieve optimum performance. Usually addition levels of nanofillers are less than 5%, which significantly impact weight reduction of nanocomposite films. This dispersion process results in high aspect ratio and surface area causing higher performance plastics than with conventional fillers [40]. Reference [28] developed whey protein isolate films embedded with $Ti0_2$ and Sio_2 nanoparticles for improved mechanical properties by solution casting. The addition of nanoparticles strengthened the way protein isolate film, as evidenced by tensile stress analysis; such films can potentially become effective packaging material to enhance food quality and safety.

CONCLUSSION

Development of biodegradable polymer solve the menace of discarding the plastics leading to complete bioassimilation of the plastics. The application of nanotechnology would expand the use of edible and biodegradable film has been related to improvements in overall performance of biopolymers, enhancing their mechanical, thermal and barrier properties, usually even at very low contents. Thus, nano-particles have an important role to improve feasibility of use of biopolymers that reduce the packaging waste associated with processed foods this support the preservation of foods by extending their shelf life.

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