Preparation and Characterization of Irradiated Bioplastic from Cassava Peel – A Review

Fong Chui Nee1 and Siti Amira Othman1

1Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia, 84600, Pagoh, Johor.

Abstract. The conventional plastic bears unavoidable responsibility for the massive scale generation of garbage. The bulk of the market is mostly made up of fossil-based plastics and the worldwide environmental pollution generated by them is growing increasingly problematic. Agro-waste product is probably a good way to make bioplastic. In fact, biodegradable plastic is indeed a good alternative to replace the petroleum-based plastics. Besides, making good use of agriculture waste can assist in diminishing waste accumulation. Cassava peel is a type of waste from cultivating activities that has the potential in making bio-based plastics. This research will focus on the preparation and characterization of bioplastic from cassava peel. Several related characterization methods such as XRD, SEM, FTIR, TGA will be discussed. The main purpose of this review is to fabricate and produce bioplastic samples from cassava peel with the addition of different ratios of sorbitol and chitosan.

1 Structure and Uses of Plastics

Plastics are widely utilized polymers in our daily lives, particularly in packaging applications, aerospace industry, construction, electrical and electronic applications, automotive, furniture and in medical and healthcare applications. Plastics are a broad category of artificial or sometimes semi-synthetic elements that contain polymers as a primary component. Plastics can be shaped, extruded, and pressed into any solid objects of diverse forms due to their flexibility and fluidity. This versatility, along with a variety of other features like lightweight, durability, flexibility, and low-cost production, has led to its widespread application. Most conventional plastics are generated from petroleum-based substances such as natural gas and crude oil. However, current commercial technologies start to utilize renewable material alternatives such as maize and agricultural waste products.

The majority of plastics consist of polymerized organic polymer. The huge bulk of the polymers are made up of carbon atom chains with the addition of oxygen, nitrogen, or sulphur molecule. These chains are made up of multiple repeating units made up of monomers. Each polymer chain is made up of thousands of repeating units. The backbone is the component of the chain that connects a great amount of repetition units. To alter the characteristics of a plastic, various molecular groups known as side chains are made attached to the backbone that is typically suspended from the monomers prior to the monomers themselves are connected to form the complete chain of polymers. The chemical composition of the polymer’s backbone and side chain is used to classify plastics. Acrylics, polyesters, silicones, polyurethanes, and halogenated polymers are some examples of important groupings.

1Corresponding author: sitiamira@uthm.edu.my
Plastics are classed based on the chemical method used to create them, such as condensation, polyaddition, and cross-linking. Physical parameters such as hardness, density, tensile strength, heat resistance and glass transition temperature can also be used to classify them into groups. On top of that, plastics can also be distinguished based on their resistance and susceptibility to certain chemicals and procedures in several types of organic solvent exposure, oxidation process and ionizing radiation. Several example of common uses of plastic include fibers (polyamides), compact discs (polycarbonate), fibers and textiles (polyester), bottle caps (polypropylene) and food packaging (polyvinylidene chloride) [21].

2 Biodegradable Plastic

Biodegradable plastics are those that can be deteriorated by living creatures, often microorganisms, into the water, carbon dioxide, and biomass. The term ‘biodegradable’ is defined as a substance or object that has its capability of being decomposed by bacteria or other living organisms and thereby avoiding waste pollution problems. Renewable raw sources, microorganisms, petrochemicals, or mixtures of all three are often used to make biodegradable polymers. Disposable products such as packaging, tableware, cutlery, and food service containers are made from biodegradable polymers. Biodegradable plastics are those that can be broken down by microbes into carbon dioxide, methane and microbial biomass. Microorganisms utilize the carbon substrate from plastic polymers to digest energy and carbon. This process can take place in both aerobic and anaerobic environments [1].

2.1 Bio-Based Plastic

Bioplastics are bio-based polymers or in other words, biodegradable plastics. The word bio-based refers to a substance or product that is partially generated from biomass. Bioplastics are plastic derived from biomass such as maize, sugarcane, or cellulose [2]. They are the most biodegradable and compostable polymers, which are often manufactured from plants such as bamboo and sugarcane rather than fossil fuels and petroleum. Bioplastics manufactured from renewable materials can be recycled organically by natural organic processes, reducing the consumption of fossil fuels and saving the environment. The issue of resource shortage over the last few decades had raised the world’s awareness and these results in the growth of environmental challenges. Petroleum resources are heavily utilized in the production of these polymers, raising concerns about both economic and environmental sustainability. Overdependence on petroleum resources can be reduced by developing bioplastics from biological resources, or more precisely, yearly renewable resources. Thus, various research activities have been conducted to determine new alternatives. The methods for generating bio-based polymers may be divided into three groups. To achieve the performance criteria, one method is to partially change natural bio-based polymers, such as starch, cellulose, and lipid extraction, separation, and purification. Furthermore, bio-based monomers can be synthesized using traditional either chemistry or fermentation and finally by polymerization. This is frequently used in the production of polyactic acid (PLA). There are four types of biodegradable polymers. First, biodegradable polymers are derived from biomass and natural resources. The term “biomass” refers to non-fossilized and biodegradable organic substances derived from plants, animals and microorganisms. Another type of polymer is that formed by microbial fermentation of agricultural materials. The third type of polymer is one of those that is produced through polymerizing oligomers or monomers.
microbial fermentation. Finally, certain polymers made from fossil fuels are biodegradable [3].

According to the bioplastics market development statistics 2020 by European Bioplastics, bioplastics account for around 1% of the more than 368 million tons of plastic generated each year. However, as demand grows and more complex applications and goods emerge, the bioplastics market is expanding and diversifying. According to the report, global bioplastics capacity is expected to rise from roughly 2.11 million tons in 2020 to over 2.87 million tons in 2025. Bioplastics substitutes are available for practically every traditional plastic material and application. With the commercialization of further bioplastics materials, such as polyethylenefuranate (PEF), bio-based polypropylene (PP), but also polyhydroxyalkanoates (PHAs) and polylactic acid (PLA), manufacturing capacity will continue to grow and diversify over the next five years [2].

3 Bioplastic from Agro-Waste Product

The term "bioplastic" can refer to either bio-based plastics made from biomass and renewable resources, such as Polylactic acid (PLA) and Polyhydroxyalkanoate (PHA), or plastics made from fossil fuels, such as aliphatic plastics like Polybutylene succinate (PBS), which can also be used as a substrate by microorganisms [4]. Bio-based plastics are created using a variety of sustainable bio-based feedstocks or in other words, agro-waste products. Agro-based feedstocks are plants that contain abundance of carbohydrates, such as corn or sugar cane. Agro-waste is defined as waste generated from the various agriculture sector. Manures, bedding, plant stalks, hulls, leaves and organic matter are some examples of agro-wastes. Agro-waste product is often obtained from the results of farming and cultivating activities. In an agricultural system, agro-waste is commonly unwanted and is thrown [5]. Agro-waste piling may be hazardous to one's health, safety, the environment, and one's appearance. As a result, this is an issue that demands proper disposal [6]. Thus, biodegradable polymers may make major contributions to material recovery, landfill reduction, and the use of unwanted renewable resources and agriculture by-products [7]. In recent years, there has been a surge of interest in the creation of biodegradable packaging materials made from renewable natural resources (such as crops), notably in EU nations and the utilization of renewable resources has been rejuvenated [7] On top of that, if agricultural by products can be properly managed, it would have lessened the environmental effect upon their disposal and it would also be technically and cost-effective [8]. Although bioplastics are environmentally beneficial materials, they do have significant drawbacks, such as high production costs and poor mechanical qualities. The disadvantage of high manufacturing costs can be mitigated by employing agriculture wastes, for example, low-cost renewable resources [9].

4 Lifespan and Degradation of Bioplastic

Bioplastic of different types have their own lifespan and lifecycle. The period of lifespan is dependent on their based-type. Their degradability is affected by physical and chemical structure within the bioplastic materials. However, factor affecting the rate of biodegradation and their lifespan is the thickness of the bioplastic. A thicker bioplastic material will have a longer biodegradability duration [10]. There are several conditions needed that depends on the percentage of biodegradation period for different starch-based bioplastics, for example bioplastic made from potato (~85%), starch-based (14.2%), mater-bi bioplastic (68.9%), mater-bi bioplastic consists of 60% starch and 40% resin (26.9%) [11,23].
5 Cassava Peel

Cassava is an extremely essential food crop and a large proportion of it that it can be utilized commercially to produce starch. Cassava is another important resource utilized in the manufacturing of biodegradable plastic. It is one of the most abundant sources of starch. Cassava roots contain up to 35% starch, soluble carbohydrates, and lipids, making starch extraction from its peel or skin much easier [12]. Cassava is a popular raw material due to its nontoxicity, biodegradability, and biocompatibility. In today's world, starch accounts for 66% of worldwide biodegradable plastic. The manufacturing of biodegradable polymers from cassava starch, which when disposed of readily decomposes into carbon dioxide, methane, and biomass due to the enzymatic action of microorganisms, is therefore highly significant. Cassava is mostly a shrub that grows vegetatively. Its starch from its peel or cassava itself can be broken into two types of polymers namely amylose and amylopectin. Amylose can provide for 20-30% of the overall quantity, whereas amylopectin accounts for 70-80%. A high amylose concentration in starch indicates reduced gel strength and stickiness, but a high amylopectin level indicates higher binding potential [13]. The development of multiple biodegradable polymers by the use of formulations including various elements to boost their strength [13]. During the manufacturing of several of the reported biodegradable plastics, he added different plasticizers to the materials, which enhanced their thermal stability, flexibility, and stretchability by diminishing their intramolecular pressures.

6 Plasticizer

A plasticizer is a chemical that is a transparent, colorless and greasy liquid applied to the material to soften and stretch it, improve its plasticity, lower its viscosity, or reduce friction during manufacturing. Plasticizers are commonly utilized in a variety of industries in making medical equipment, food film, floor coverings, pipes, electrical appliances, and wire, insulator, automotive trim, and other goods. Plasticizers are also employed in other applications such as paints, which need particular coating qualities [14]. Additionally, plasticizers are additives, often tiny organic molecules, that lower the temperature of the glass-transition ($T_g$) of the polymer with which they are mixed, resulting in flexible or semi-rigid products with enhanced processing properties [15]. The most widely used plasticizer is di (2-ethylhexyl) phthalate (DEHP).

6.1 Role of Sorbitol as Plasticizer

Plasticizers are required components in the production of starch films since starch-only films are excessively hard, brittle, and inflexible. Plasticizers such as glycerol and sorbitol, which are often employed in starch film manufacturing, increase the plasticity of starch films by decreasing intermolecular hydrogen bonding and increased intermolecular space between polymers the following ionization into the network of starch polymers [16]. The application of sorbitol originates from its ability to reduce film breaking during storage and handling processes [18]. Preliminary investigations and prior research revealed that starch films are exceedingly brittle at low plasticizer concentrations and exceptionally soft, sticky, and difficult to be peeled off from the casting surface at high plasticizer concentrations. In general, sorbitol as a plasticizer can shrink the polymer network by increasing the intermolecular space between polymer chains, resulting in the flexibility of
starch films. The kind and concentration of plasticizers also have an impact on film morphology [17].

7 Chitosan

Chitosan is a polysaccharide that is linear and cationic with a high molecular weight. It is made up of N-acetyl-D-glucosamine (acetylated unit) and -{(1,4)-linked D-glucosamine (deacetylated unit) in a random order. Chitosan is created by deacetylation of chitin using an alkaline process. More than ten gigatons of chitosan have been claimed to have been created from agro-waste, primarily crustacean shells, providing enough raw material to be utilized or value-added for desired uses. Chitosan is created by deacetylation of chitin using an alkaline process [3]. The structure of chitin and chitosan consists of different element that attached via a bond such as hydrogen, oxygen and more [22].

Furthermore, chitosan has been discovered to be incapable of being dissolved in water and alkaline solutions but can be dissolved in dilute acid solutions. This is because of the presence of protonated amino groups, resulting in positive charges dispersed along the molecular chain (−NH3+) [19]. In addition, being a non-toxic substance with compostable and permeable features, chitosan aid in the prevention of contamination to the environment when discarded as trash and is capable of improving the micro ecological qualities of soil [20]. As a result, chitosan has emerged as a possible raw material for the development of biodegradable films for food packaging applications. Furthermore, chitosan can be combined with various biodegradable polymers to increase desirable qualities and overcome the limitations of pure chitosan [3].

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