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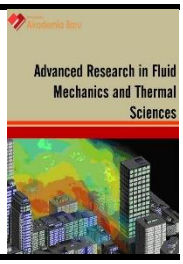

Gamma Radiation Effects on Biodegradable Starch Based Blend with Different Polyester: A Review

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ABSTRACT

Effect of gamma radiation to biodegradable starch based had been developing and increase interest among the researchers. Starch blend with various synthetic and natural polymers will produce different result for each of it. This paper discussing for four polyesters that commonly used in the industry which are Polycaprolactone (PCL), Glycerol, Polyvinyl alcohol (PVA) and Polyethyleneglycol (PEG 300). By refer result from previous report, irradiated starch blend with PVA, PEG 300 and glycerol give positive result on mechanical and barrier properties. Tensile strength, water absorption and radiation effect for each polyester blend with irradiated starch were discussed. Gamma radiation improve the mechanical and barrier properties.

1. Introduction

The use of biodegradable packaging is very widespread nowadays because it has been suggested that biodegradable play an important role in reducing plastic waste composition [1]. Biodegradable refers to the ability of material to decompose to carbon dioxide, methane, water, biomass and inorganic compounds and return to nature within a short time after disposal [2]. Figure 1 shows the category of bioplastic. The main advantage of biodegradable packaging applies to environmental properties, primarily when it comes to the handling of waste plastics and the effects of their decomposition on the environment. There is large category of bio-based polymers and the most common bio-based is starch based bioplastic [3]. That is because 75% of all organic material on earth is present in form of polysaccharides and mostly of polysaccharide is a starch [4]. Starch based plastics are mostly made from wheat, potatoes, rice, and corn.

The advantage of starch based are improve product quality, cheap, natural resources and abundant [5]. Starch based also offer a wild range of applications such as mobile phone casings, foil, molds, tins, cups, bottles, and packaging devices [6]. In spite of that, starch-based are brittle and hydrophilic therefore it is limiting their processing and application. In order to overcome this

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problem, starch blend with various synthetic and natural polymers. Blends of starch with different compostable plastics produce different result in insolubility, strength and more. Usually the blend improves resistance of water, processing and mechanical properties [7]. The most commonly used biodegradable polyester were polylactic acid (PLA), polybutylene adipate terephthalate (PBAT), polycaprolactone (PCL), polybutylene succinate (PBS) and polyvinyl alcohol (PVA) [4,8]. This type of biocomposite offers the advantages of being light weight, low cost, biodegradable, and exhibits reasonable strength and stiffness [9].

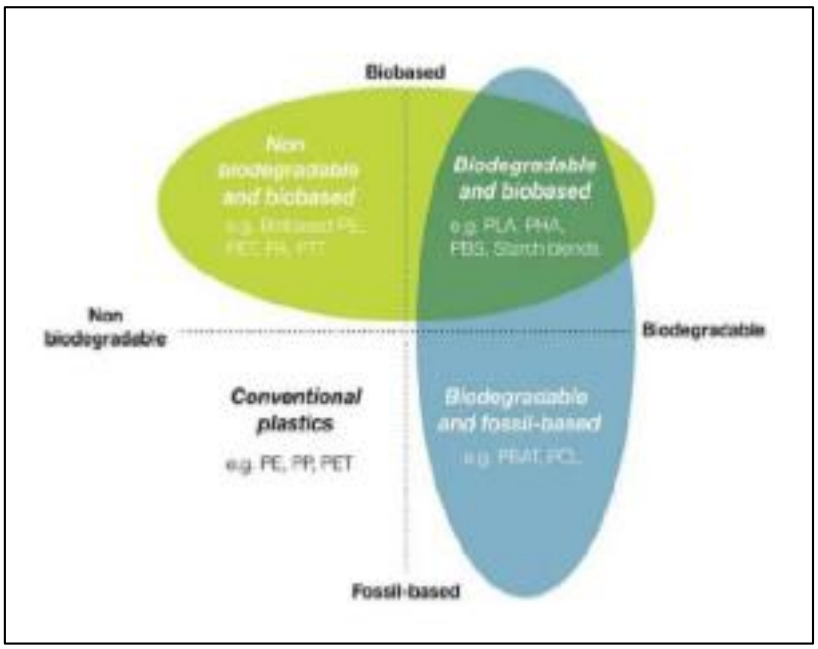

Fig. 1. Category of bioplastic [2]

Starch-based There are increasing interest, the exposure to ionizing radiation of starch based may lead to formation of free radical, ions, excited state and many very reactive intermediates, and it will involve in many chemical reactions even after the irradiation process [10]. Gamma radiation and electron beam is most common used radiation in industrial. For gamma radiation is very penetrating from the other types of radiation. However, electron beam has availability on different machine designs and different energies. The main purpose irradiation of polymer is to modified polymer material crosslinking, degradation and grafting. Gamma radiation well known as a very convenient tool for modified the polymer [11]. Effect of ionizing radiation to starch is that the polymer undergoes breaking of glycosidic bonds and the degradation having possible modifications of its crystalline structure [12]. Starch contain 2 polysaccharides that is amylose and amylopectin. The ratio of these polysaccharides depends on starch source. Based on this, the result should be different for each starch source used [13]. According to Brant *et al.,* [10], ionizing radiation improve the tensile strength and barrier properties of starch based for food packaging.

There is a lot of research to improve the starch based some of it are blend with other natural polymer or artificial polymer and ionizing radiation [4,13]. Because of that, this paper will present the previous result on effect of gamma radiation on starch-based blend with different polyester.

2. Methodology

Based on Krystyna [14], starch was exposed to Cobalt-60 with doses 5, 10, 20 and 30 kGy after that glycerol were added to the irradiated starch to improve flexibility and Instron testing machine

were used to test mechanical properties while Scanning Electron Microscopy (SEM) were used to test structural properties. Meanwhile Natalia [15], added PEG (300) to irradiated starch to improve the strength. Before PEG (300) were added, the starch was irradiated using Cobalt-60 then the mixture was mixer for 3 minutes. Figure 2 shown illustration of overall flow of the method used.

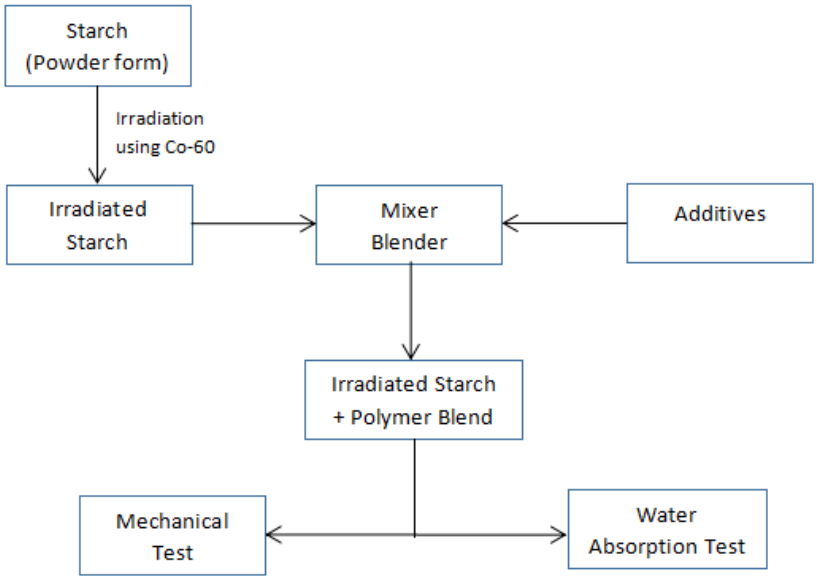

Fig. 2. Overall flow of the method used

2.1 Starch Irradiation

The irradiation of starch (in powder form) was performed by gamma radiation from a source of cobalt60. The dose should be determined before an application because irradiation of natural polymers can effect in both degraded and cross-linked polymers [16]. The dose is depending on what result or effect the researcher want.

When the starch exposed to gamma radiation, it produces free radical which is will modify the amount and structure of starch fraction [17]. The viscosity decreases when the doses increases which lead to increasing water solubility and acidity in starch [11,17]. The changes of viscosity were the causes of degradation. Gamma radiation also influence oxidative degradation [15].

2.2 Starch Blend

In this paper, starch that had been irradiated was blend with different biodegradable polyester which is; a) PVA, b) PEG (300), c) Glycerol and d) PCL.

Depend on the type of polymer materials, ratio between polymer, miscibility and phase behavior resulted varied on the properties of polymer blend [18]. PVA also known as synthetic biodegradable polymer which can be easily biodegraded and possesses excellent mechanical properties. It also reported the best option to be blended with starch [8]. Based on Klanarong, PCL is most used starch blend because of its low melting temperature and high susceptibility to amylase and lipase hydrolyses [19]. Meanwhile, PEG (300) were used to improved mechanical properties [15] and glycerol is to improved flexibility [14]. Changes of starch physicochemical properties were depending on total absorbed dose by the polymer [10].

3. Measurement and Analyses

The most important aspect for biodegradable were the mechanical and barrier properties. Mechanical properties include tensile strength usually performed using Instron Machine [11,14]. For barrier properties, the solubility in water of the sample were the main aspect. Absorption of water usually calculated using an Eq. (1) [10,15].

$$Water\ Absorption\ (\%) = \frac{WetMass - DryMass}{WetMass} x100 \quad (1)$$

3.1 Mechanical Properties

Mechanical tests include tensile strength and elongation at break. Mechanical properties of most plastic materials at an economical cost make them desirable to all their user. For this reason, the mechanical properties may be considered the most important physical properties of polymers for most applications. In particular, the stress strain test is the most widely test of all the mechanical tests. Blending process and ionizing radiation are expected to have great effects on mechanical properties of the blends [11].

Comparison between 4 polyester shown that PVA have both increasing for tensile strength and elongation at break [10] and PCL have both decreasing [10]. However, for PEG (300) and glycerol have increasing for tensile strength and decreasing for elongation at break [14,15]. This is because the effect of gamma radiation is depending on the compatibility between polymers and the sensitivity of the individual polymer toward the irradiation [11]. The tensile strength for PVA blend with irradiated starch was improved by radiation-induced crosslinking reaction. However, three types of species are formed under high energy irradiation, and may become trapped in polymer, ionic species, radicals and peroxides, both radicals and peroxides can initiate post irradiation, the various active centers, can lead to different chemical transformations such as crosslinking and degradation [8].

3.2 Water Absorption

Water absorption is an important factor in the evaluation of biodegradable properties of polymers. This is because water absorption is very essential for thrive of the microorganisms, which depends on the presence of moisture, water and nutrients. Thus, the higher the ability of the material to absorb water, the higher is the capability to undergo biodegradation.

Starch are totally soluble in water which is it do not offer good quality of products. Therefore, to improve the water-resistance properties of starch, the gamma irradiation treatment was used. For water absorption, the result shown that for all four polyesters have increasing in percent [8], [10], [14,15]. That is because effect on the hydrophilic or hydrophobic properties depend on starch and the polyester content indicate the compactness is a major factor influencing for water absorption [14]. The irradiated polymer tends to become more hydrophilic or hydrosoluble than the non-irradiated.

3.3 Effect of Gamma Radiation on Biodegradable Starch Based with Different Polyester

The result from the previous report shown that tensile properties for PVA, PEG (300) and glycerol increasing when the dose is increase. But for PCL tensile properties decreasing when the dose exposes to the starch increase. Based on [20], it has been reported that the tensile strength increasing with increasing of the radiation dose in the dose ranges of 30-70 kGy, but when the dose was increase

more than 120kGy, the tensile strength decreased slightly [20]. For elongation at break (%) will decrease with increasing radiation dose [15]. The absorbed amount of water increased with the increasing of irradiation dose of starch blend with each of polyester [8,10,14-15].

Blending process and gamma radiation were expected to have great effect on mechanical properties on polymer but this effect was depending on compatibility and sensitivity of the polymer toward radiation [11]. Based on Wittaya, by using gamma radiation on starch-based blends resulted increasing in tensile strength and percent elongation [18]. It's also improved water vapor permeability. This prove that the gamma radiation led to improvement of mechanical and barrier properties of irradiated starch blend film. Table 1 below shown the summary effect of radiation on properties of starch-based blend with different polyester.

Table 1
The summary effect of radiation on properties of starch-based blend with different polyester

Polyester	Tensile strength	Elongation at break	Water absorption	Ref
PCL	Decrease	Decrease	Increase	[10]
Glycerol	Increase	Decrease	Increase	[14], [15]
PVA	Increase	Increase	Increase	[8]
PEG 300	Increase	Decrease	Increase	[14],[15]

4. Conclusions

This paper is aimed to discuss on the effect of gamma radiation on starch blend with different polyester. Overall the result of effect of gamma radiation on starch blend will improve the mechanical and barrier (water absorption) properties when compared to non-irradiated starch. However, different polyester blend with the irradiated starch give different result, which is polyester PVA, PEG and Glycerol give positive result but for polyester PCL have worsened the properties of barrier and those mechanical compare to non-irradiated starch. These is probably because of partial degradation of the irradiated starch. Irradiated starch blend with PVA, PEG and Glycerol affected the degradation behavior by raising the tensile strength and elongation to break. Gamma irradiation led to chemical reaction and improve tensile strength.

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