Characterization of Irradiated Wood Plastic Composites (WPCs) Consumer Product

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Abstract. This research paper emphasizes the characterization of irradiated wood plastic composites for consumer product. Throughout this research, it is precisely conducted to observe the mechanical and physical properties of WPCs and their ability to fit in the market globally. The study also carried out to promote WPCs product that came naturally from renewable sources. WPCs in this research can be defined as mixture of wood that can be replaced with pineapple fiber in a polymer matrix. Composite that used in this research mainly consists of 40% polyethylene (PE), 50 % pineapple fiber and the rest is coupling agent that enhance the WPCs mixture. After undergoes several processes such making the raw sample of WPCs mixture, the WPCs were then irradiated under required dose levels of 0.5, 1, 1.5, 2, 2.5 kGy with the aid of the Gamma Cell Irradiator. Soon after, the irradiated WPCs then undergoes characterization process using Fourier Transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscopy- Energy Dispersive X-Ray Spectroscopy (SEM-EDX). Diagnosis on the morphology of WPCs found that there was significant difference between the radiated and irradiated surfaces.

1. Introduction
Wood Plastic Composite (WPC) is a mixed material that composed from plastic fiber and natural wood. Commonly, WPCs used natural wood during the past research. However, when the discovery is conducted, the researcher also found that plant fiber oppressed the natural properties of natural wood. Plant fiber can be categorised into group of two which are synthetic and natural. Majority of the plant fiber are made up from cellulose, lignin and hemicellulose. Plant fiber can be obtained or classified depending on the parts that they are obtained from. Several parts of plant fiber are including stem, leaf, seed, fruit, root, grass, cereal straw and wood. WPC is widely used in various field such as automotive, agricultural and architectural. Because of the composite unique composition, WPCs properties can be enhanced to assume a wide array of shapes and dimensions. Due to the higher content of cellulose, WPCs can be assumed have the similar pattern as wood but varied in certain properties. The ability of the WPC to withstand higher temperature environment is also adding up the additional point.

2. Literature Review
WPCs add the chance of moisture sorption and biological degradation. The moisture process evaporates and increases gas pressure during high temperature compounding and forming process. Furthermore,
moisture content in wood can create hollowness in the finishing product and thus adverse the mechanical properties. Meanwhile, the biological degradation in WPCs. The vital requirement to maintain a lower temperature during the process is compulsory because of the risk for serious thermal degradation of the wood polymers. The mechanical properties of WPCs decrease laterally with the reduction of wood polymers usage. Polymer that are exposed to ionizing radiation, nonetheless at low doses, often endure structural changes accompanied by molecular crosslinking, grafting and chain scission reactions. Using ionizing radiation represents an economic advantage, because it reduces the use of additives in the formulas. The previous researchers [2] examined the gamma-oxidation of linear low-density polyethylene including the dose–rate effect of irradiation on chemical and physical modifications was observed. Their results showed that the lower the dose rate, the higher the degree of oxidation in terms of product formation, which were very dependent on the dose rate of initiation.

The alterations between the surface energy of the fibre and the matrix of the plastic polymer determines the final products in terms of properties of the composites. This require the addition of coupling agent to enable strong interfacial adhesion. There are several manners in which coupling and compatibilization can take place, including the improvisation of the fiber or polymer and the addition of coupling agents. It depends on the type of natural wood and plastic involved, different coupling agents and compatibilizers may be adequate. According to [1], the world has convey more attention in the environmental impact of products and the processes is gaining popularity. Research about wood-plastic composites has been acknowledged in these recent years. Different types of industries produce diverse materials, some of which have been already studied as a part of a composite. The range of the materials is enormous, and there is a wide variety of different areas of waste producers [3-5].

2. Methodology

2.1 Sample Preparation

Wood Plastic Composite are coming from the combination of plant fiber with the polymer matrix. After the pineapple stems were washed and dried at room temperature, the dried pineapple stems were cut into 5 cm lengths. These stems will then crush using hammer to be converted into smaller form for the next process. After the pineapple stem has undergone cleaning and drying process, it must undergo sieving process through meshes of 2.8 mm, 1.4 mm and 0.7 mm. The sample are then divided into fine, medium, coarse and extra size. These are the ranges of their size according to their own measurement. Firstly, fine samples must be lower than 0.7 mm. Next, medium samples are in range 0.7 mm and 1.4 mm. After that, coarse samples are also in range of 1.4 mm and 2.8 mm. Lastly, the range included is over than 2.8 mm.

Besides, preparing two different batches of pineapples according to their particle size distribution, apparent density and morphology. The density of the pineapple fiber can be calculated using empirical method. The process then moving to the process where the pineapple fiber insert into mixing blender of volume 100 cm$^3$. The next step is mixing. 20% of polyethylene was added to pineapple cellulose with the weight percentage of 20 %, 40%, 60%, 80% and 100%. There are several steps in the process to obtain WPCs sample. The steps are blending, acid treatment, sieving, weighing and drying process.

Sieving process were made in triplicates in this study in order to get the particle distribution of wood plastic composite powder. First, pineapple fiber was sieved right after the blending process to remove any big impurities and prevent particle agglomeration. In this study, pineapple fiber with the size of ≤50m was used. The size will affect the reaction during mixing and thus affect the result. During this process, there is no specific time that is being set as long as the powder can be obtained referring to the acquired size.

Plant fiber was then carried out acid treatment using 1 mole of Acetone for 30 minutes. In order to get acetone with the right mole, acid dilution process had been carried out because the laboratories did not prepare. The acid dilution process was carried out based on the calculation using equation 1 where $M_1$ is the concentration in molarity (moles/liters) of the concentrated solution, $V_2$ is the volume
of the concentrated solution, \( M_2 \) is the concentration in molarity of the dilute solution (after more solvent has been added), and \( V_2 \) is the volume of the dilute solution.

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M_1V_1 = M_2V_2 \tag{1}
\]

An acid treatment was used to remove the small quantities of lignin, cellulose and other raw materials from plant fiber. The pineapple fiber was dispersed in 1 mole of acetone, been stirred constantly for 30 minutes. Then it will be filtered by using filter paper.

After acid treatment, and filtering process, the obtained fiber was found to stick on each other and did not dry completely. Therefore, the precipitation of fiber was undergoes drying process in oven for 24 hours at 100˚C. This drying process was done to remove any moisture in it. The fiber was placed in a mould and covered by aluminium coil to avoid contamination during drying process. The weight of the fiber compound was observed to be decrease after this process due to the loss of moisture. Then the fiber compound was sieved again and the fiber preparation had been completed. This fiber compound will then used in sample preparation by mixing with polyethylene.

Before the preparation start, the fiber compound need to be weighed first before mixed with polyethylene component to form samples. There were four steps in this process which included weighing, mixing, moulding and radiation. Weighing steps should be done by using weighing balance. The mixing process should be carefully conducted to ensure both powders were well mixed and become homogenous.

The mixed material with the weight of 2g for each sample will be put into a mould. After the pressure is applied, the material follows the cylindrical shape of the mould. The cross-sectional dimension is 100 mm x 8 mm (length x width) and the shell thickness is 0.5 mm.

2.2 Irradiation Process by Using Gamma Cell Irradiator

WPCs sample finally undergoes irradiation process by using Gamma-Cell Irradiator. The specimens are treated at five different dose levels that consist of 0.5, 1, 1.5 and 2 kGy to assure the most uniform dose distribution.

The physical properties to be characterised for this study by using mass loss, water immersion test and compression test. While, the result of mechanical properties of the sample was conducted by using FTIR, SEM and EDS.

4. Results and Discussion

4.1 Characterization by Using FTIR

FTIR Spectroscopy analysis was conducted to analyze the presence of various functional groups in between plant fiber and high-density polyethylene (HDPE) that responsible for the mixture of element inside wood plastic composites (WPCs). The observed intense bands then were compared with standard valued to identify the functional groups.

All spectra were identical with a sharp and strong intensity peak at 3393.09 cm\(^{-1}\) assigned to O-H stretching indicating the presence of alcohol and amines. On the other part, the band at 2914-2915 cm\(^{-1}\) arising from medium C-H stretching of alkane and strong and broad O-H stretching of carboxylic acid. The band at 718.4 cm\(^{-1}\) was assigned for benzene derivative.

The band in range 1460-1545 cm\(^{-1}\) was assigned for N-H stretch vibration present in the amide linkages of the composites. These functional groups have role in stability/capping of element as reported in many studies. The bands at 715-720 cm\(^{-1}\) region could be attributed for C-Cl (alkyl halides) strong stretch vibration for the composites respectively.

The band at 718 cm\(^{-1}\) exemplifies the same bonding as they positioned in between the previous band. In the presence of oxygen, the photo-oxidation of polyethylene leads to the formation of hydroxyl that consist of mainly hydro peroxides and alcohols and carbonyl groups that consist of mainly ketones,
esters and acids which are easily detectable by infrared spectroscopy, respectively. It may be concluded that the infrared signals associated with the aldehyde functional groups became stronger by increasing the radiation dosage.

4.2 Characterization by Using SEM

Microstructure of WPC was observed by using field emission SEM to investigate the optimum effect of before and after gamma radiation. SEM image shows that there was clear gap between plant fiber and polymer matrix in irradiated samples. It was observed that weak interfacial bonding exist between polymer blends and plant fiber in WPCs. The long, stringy strands are evident upon analysis of WPC of cracked surface.

The spongy crack mechanism shown by the white arrows in Figure (a) show stretched region of large plastic in WPC. Figure (b) is non radiated WPC. An effective coupling agent can improve the interfacial adhesion and bonding consequently enhance the mechanical properties of WPCs. In this research, acetone was used as a coupling agent to form stable bonding between pineapple fiber and HDPE polymer matrix. This means that the stress was well propagated between filler and polymer matrix, resulting in enhanced mechanical properties.

In the irradiated samples, the effects of radiation show that it depends on the dose applied to the sample. Moreover, for these samples, a loss of weight which is less than 1% after 2 kGy irradiation and about 1.50% after the 2 kGy dose was observed and a small visible yellowing appeared already afterwards. These phenomena were most probably sign of degradation. Irradiated samples display a slight improvement of more smooth surfaces than those unirradiated, most probably due to a reorganization of the matrix chains during irradiation. The most obvious changes were achieved already after a dose of 2 kGy. The irradiation dose increases when the crosslinking density between the resultant copolymer chains increases. This limits the chains of the prepared copolymer to expand and enlarge consequently decreasing the amorphous phase of the composites itself.

Figure 1. FTIR spectra on WPCs sample.

Figure 2. WPC of (a) Irradiated (b) Non-radiated wood plastic composites.
4.3 Characterization by Using EDS

Energy Dispersive X-Ray Spectroscopy (EDS or EDX) is used to analyze the elemental composition of the sample. The mechanism of EDS involving the detection of X-ray emitted from the sample by the electron bombardment.

**Figure 3.** EDX spectrum on WPCs sample shows element inside the composite.
It can be concluded that EDX spectrum reveals strong signal in the carbon region and confirms the formation of wood plastic composites. Fractured white wood plastic composite generally show typical optical absorption peak approximately at 2.2 keV due to surface reverberation. Carbon (68.64%) was the major constituent element, compared to other element, oxygen (30.26%), Silicone (0.42%) and Calcium (0.68%) as shown in Figure 3. EDX profile showed strong signal for carbon along with weak silicone and calcium peak which may have originated from the raw materials of pineapple fiber, high density polyethylene and acetone that are formed when they mixed together., thus indicating the reduction of carbon into major element in wood plastic composite. Other peak corresponding to other element in the EDX is the fact that sample was coated with Au (Gold). There were no peaks observed for gold compounds. This confirms the reduction of gold compounds to wood plastic composite as shown in the spectrum.

5. Conclusions
Pineapple leaves and plastic from polymer matrix were recycled to produce WPCs with characteristics that similar to commercialised wood which are innovative, cheap, good appearance, durable and effective. The mechanical and physical properties proved a reasonable and trusted WPCs product. The WPCs sample produced in this research paper preserving properties.
1. Higher dose of gamma ray absorbed by the composites shows higher strength of the sample.
2. The longer the sample expose to maximum temperature, the obvious the cracked surface morphology of the sample.
3. The more the concentration of polymer matrix used, the more stable the composition of the composite itself since plant fiber exhibit natural properties of the wood thus needing usage of coupling agent to alter the bonding between the composites.
4. The usage of coupling agent shows that bonding between plant natural fiber and polymer matrix can be enhanced thus improving the quality of composites produced.

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