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Mechanical Analyses of Polyethylene/Polypropylene Blend with Photodegradant

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ABSTRACT

Background: The use of thermoplastic material is increasing in all industries and human daily lives especially polypropylene (PP) and polyethylene (PE). Additional of PP into PE could impart extra mechanical strength of the final products. This study analysed the mechanical strength and structural changes of different six PE/PP blends with oxidative photodegradant. Miscibility of PP into PE resin during compounding process was made possible with acid compatibiliser (C1). **Objective:** In order to induce degradation of the blends, the compounded materials were added with oxidative photodegradant. Different percentages of photodegradant were added into PE/PP composite to test its ability to induce photodegradation upon weathering. **Results:** In this study, it is proved that by blending PE with minor percentage of PP have contributed to the incremental of mechanical properties on the product before being weathered. The PE/PP blend samples were tested and it was found that by adding 20% and 30% of PP into PE during compounding resulted in increased tensile strength and elongation at break with lesser effect on Young's modulus. After weathering for one and two months, it is shown that tensile strengths of samples were decreased. **Conclusion:** The result showed that after weathering, the mechanical strength of samples reduced and photodegradation of samples have been initiated, evidently for formulation F3, F5 and F6 of the blends.

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INTRODUCTION

Thermoplastic is used widely around the world in many different sectors due to its tough mechanical strength, durability, excellent process ability and toughness (Roy *et al*. 2006). Normally called as plastic, this material possesses good thermal and electrical insulation properties, and high resistance to chemicals. There are two types of plastics that are commonly used in industries such as agriculture, construction, and domestic uses namely polyethylene (PE) and polypropylene (PP) (Kyrikou *et al*. 2011). PP is cheap; possess good electric insulation, provide excellent chemical/oxidant/reducing agent resistance, good process ability, toughness, and flexibility. PP is a linear hydrocarbon polymer containing little or no unsaturation. PP is the lightest plastic with specific gravity 0.91 (Takahashi and Kimura, 2012). The material acquire excellent chemical resistant thus making it possible to component for many products such as households and packaging materials (Roy *et al*. 2006). PE consists of seven categories according to its properties and chemical characteristics. However, according to market studies, three types of PE that conquer the plastic market in sold volume are high density polyethylene (HDPE), linear low density polyethylene (LLDPE) and low density polyethylene (LDPE). It is known that PP and PE have many similarities in their properties, particularly in their swelling and solution behavior and in their electrical properties. However, the presence of a methyl group attached to alternate carbon atoms on the chain backbone of these polymers can alter their properties in many ways (Brydson, 1999). Additionally, polypropylene has higher strength than polyethylene by 30%. Both polymers could bring possible environmental problem after their usages. They are very stable and hence remain inert to degradation and deterioration leading to their accumulation in the environment, and, therefore creating serious environmental problems. Polymer blend offers enhanced mechanical properties (Yousef *et al*. 2011) and by adding photodegradant into the compound, photodegradability of the polymer could be achieved.

Compatibilisation of polypropylene/polyethylene blends can be accomplished by addition of copolymer by reactive blending, or by post-blending treatment, using chemical cross linking, electron beam or γ-radiation (Karger-Kocsis, 1995). In order to blend polyethylene and polypropylene together, compatibiliser is used (Datta and Lohse, 1996) whereby it provides miscibility to materials that are not or partially miscible, so that a

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homogenous product can be produced during processing. This additive works by reducing the interfacial tension and are concentrated at phase boundaries. In conventional usages, virgin PE or PP are used including for agriculture which has caused serious environmental problem and not economically feasible for recycling or energy recovering due to their nature of uses. Conventional materials has very slow degradation rates up, nearly hundreds of years to degrade thus making it a huge compile of plastic wastes. Since the biodegradable polymer made from PLA is expensive and are not suitable for long term usage due to high water absorbance properties (Shimao, 2001)), it is important to explore the potential of oxidative photodegradant as PE/PP blends' additive. Previous study (Rahmah *et al*. 2011) have resulted the development of oxidative photodegradant thermoplastic additive. The oxidative photodegradant can be used in minute amount (5%) to impart degradability in polymer. It had been tested by determine its tensile, modulus, its elongation showed degradability for less than 3 months when being exposed to weathering.

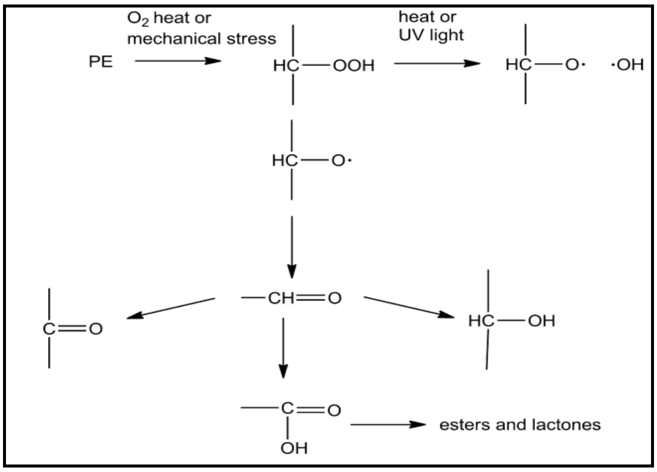

Fig. 1: Photodegradation reaction of polyethylene (Wiles and Scott, 2006).

The aim of degradable polyolefin design is to retain functionality as a commodity plastic for the required service life but degrade to non-toxic end products in a disposal environment (Ammala *et al*. 2011). Over the last decades; many researchers have done tests using PP and PE. However, there are lack of knowledge for the different composition blending of PP and PE. PE showed high resistance towards degradability, taking more than 6 months for degradation initiation to occur, while a 30 μm PP film took approximately 3 months to start degrading (Rahmah *et al*. 2011). Hence the study of PE/PP blends need to be done as different blends may cause different degradation initiation rate and to formulate the most accelerated blend.

MATERIALS AND METHODS

Main polymer material, LLDPE extrusion grade 0209SA with melt flow of 1.0 supplied by Petlin Petronas and PP, i102 supplied by MTBE PP Petronas with melt flow 10 were used. An acid compatibiliser, C1 was added with fixed 1% compositon after incorporation of two different content of degradable masterbatch which are 3% and 5%. Fixed composition of 0.5% carbon black masterbatch PE based code number MB8605 supplied by Plasmacolor (M) Sdn Bhd were also introduced before being discharged to single screw film blown extruder. Table 1 shows the formulation used. PE, PP and degradant masterbatch were weighed in according to formulation above as in Table 1. The materials were mixed before feeding into hopper of film blow moulding machine.

Table 1: Formulation of Blends.

Formulation	PE/PP (%)	Degradant M/batch (%)	C1 (%)	Carbon Black (%)
1	PE	5	-	0.5
2	80/20	5	1	0.5
3	70/30	5	1	0.5
4	PE	3	-	0.5
5	80/20	3	1	0.5
6	70/30	3	1	0.5

Temperature used for film blowing to produce thickness of 0.06 mm and size of 6 x 9 inch of film were set from 160ºC to 190ºC. Films were blown to the appropriate size and thickness by controlling air pressure, rotor and uptake speed. Tensile testings of thin plastic sheeting using Instron Tensile Tester in accordance with

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ASTM D882 were performed. The specimens are gripped carefully to prevent slipping of the material at high loads but not to tear the material and cause premature specimen failure. Samples were subjected to uniaxial tension until failure. Tensile strength, modulus and elongation at break were determined. Differential scanning calorimetry (DSC) DSC-7 by Perkin Elmer were employed according to ASTM 3418. The differences in heat loss or gain between the sample and the reference cell are measured by this technique. In this case, the heat input needed to be maintained in both cells at the same temperature is measured (Folkes and Hopes, 1996). Samples were heated from 30.00°C to 200.00°C at heating rate 20.00°C/min, hold for 1.0 minutes at 200.00°C.

RESULTS AND DISCUSSIONS

Tensile strength was measured by the force required to break the sample. It is the maximum amount of stress that a material can withstand while being stretched or pulled before necking occurs. Tensile strength was measured in unit of force divided by area expressed by N/mm^2 or mega Pascal (MPa).The tensile strength, modulus and elongation of films were as in the Fig.2 to Fig. 3. Melt flow index also been determined to indicate the polymer melt flow. It showed that formulation 5 posses highest MFI. The melt flow of formulations (F) showed ascending pattern according the following arrangement F4 < F1 < F2 <F6 < F3 < F5. Melt flow of formulation 5 is the highest as PP content is 20% and masterbatch PE is 30%. Formulation 4 which has 100% PE has the lowest melt flow as it is of extrusion grade PE with intrinsic initial melt index P of 1.0. From the result obtained, it was showed that the tensile strength of sample after exposure to weathering was lower than the tensile strength of the sample before the exposure. Comparing between formulation 1 and 2, tensile strength before and after 2 month of exposure (5% of photodegradant masterbatch) decreases their tensile strength to 35.49% and 25.15% respectively.

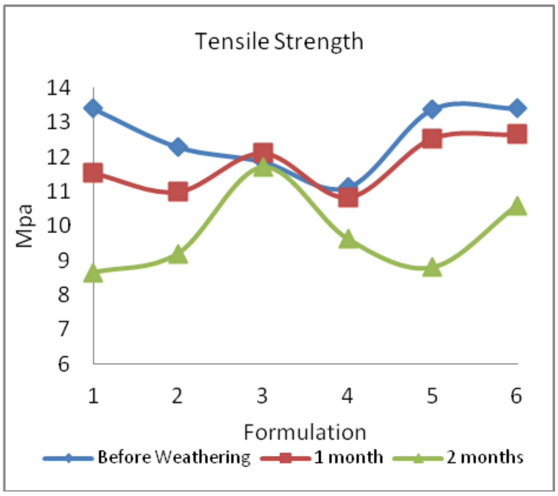

Fig. 2: Evolution of tensile strength for different formulation and exposure time.

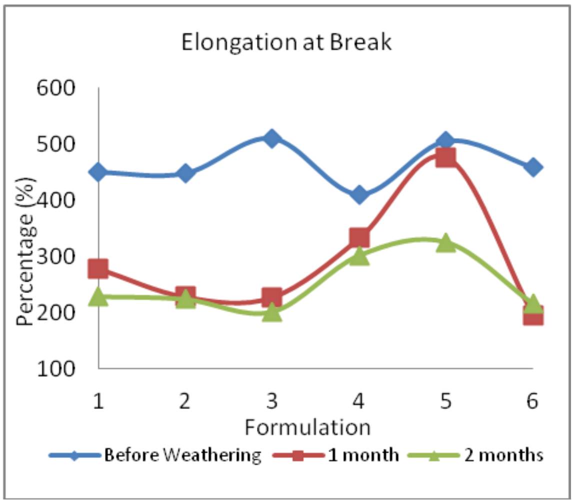

Fig. 3: Evolution of elongation at break versus formulation number.

While the tensile strength before and after 2 month of exposure for formulation 4, 5 and 6 (use 3% of degradant masterbatch) exhibited of 13.48%, 34.24% and 20.94% respectively. From Fig.2, formulation 1 and 2 show similar rates of decreasing tensile strength in the first and second month of weathering which are from 13Mpa (zero weathering) to 11.5Mpa (first month of weathering) and 8.6Mpa; 12.3Mpa (zero weathering) to 11.0Mpa (first month of weathering) and to 9.2Mpa (second month of weathering) respectively. The more stable tensile strength in formulation 2 compared to formulation 1 is due to 20% PP content in the blend. While in formulation 3 which has composition of 30% PP blended with 70% PE, there were no significant changes in tensile strength until third month of weathering. The tensile strength for formulation 3 are 11.9Mpa (zero weathering), 11.8Mpa (first month of weathering) and 11.7Mpa (second month of weathering) thus shows that formulation 3 required highest force per unit area upon failure due to additional of PP in the blend; thus proving that the ratio of 70:30 of PE to PP give toughest end product for 2 months of usage under tropical environment.

Formulation 4 showed consistent tensile strength with small changes after two months of weathering. This is due to the composition which was pure PE material with only 3% of degradant which was also PE based. Formulations 5 and 6 showed similar pattern of tensile strength breakdown after first month of experiment were both formulations exhibited small changes in first month; 13.4Mps in zero weathering, 12.54Mpa in first month of weathering and 13.41Mpa in zero weathering, 12.66Mpa in first month of weathering respectively. However, after two months of weathering, formulation 5 showed significant reduction from 12.54Mpa to 8.8Mpa of tensile strength showing reduction of 3.74Mpa in tensile strength, while formulation 6 showed lesser reduction which was from 12.7Mps to 10.6Mpa after two months of experiment with 2.6Mpa reduction. In formulations 1 and 4, both samples were not blended with PP; and showing reduction in tensile strength due to 5% and 3% photodegradant respectively. This showed that by adding photodegradant to virgin resin of PE, it could initate photodegradative reaction. From the results obtained the uses of photodegradant masterbatch of 3% possess higher tensile strength than the use of 5% photodegradant masterbatch. Formulation F3 and F6 (30% of PP) exhibited moderate degradation rate as the PP methyl end group could be hindered from oxidation and photo sensitization process although PP has the capability to degrade due to the methyl group presence. Hence blending with PE would be able to modify the degradation rate.

Elongation at break measures the change ratio between initial and after the breakage of test specimen. It is also known as the capability of a material to resist changes of shape without the formation of cracking. The elongations at break of the samples are as in the table Fig. 3. It is showed in Fig 3 that formulations 1 to 3; there were less significant increase in elongation at break. This is due to the increase of PP in the composition of the PE/PP blend. PP is of extrusion film grade having MI of 10 and it has elastomeric copolymer blend which improves its elasticity. The elongation at break after the exposure to weathering reduced to more than half than the elongation at break before the exposure. For formulations 1, 2 and 3, the decrement of elongation at break after 1 month of exposure is 38%, 49%, and 55.4% respectively. For formulation 4, 5 and 6, the decrease of the elongation at break after exposure is 19%, 5.7%, and 57% respectively. Elongation at break showed very little differences between one and two month of exposure except F5. Since the elongation was maximum using 30% PP for F3 and F6, this showed that elongation is significantly reduced by presence of more PP chain in the blend. Reduced elongation depicted brittleness formation resulted from PP methyl end group which is less elastic due after undergoing degradation process by oxidation and photo sensitization upon UV light exposure as in Fig. 4 below.

Young's modulus measuring the stiffness of the sample. It is the ratio of the uniaxial stress over the uniaxial strain. From Fig. 5, it shows that the Young's modulus before and after 1 month of the exposure were similar. However, after 2 months of exposure there was significant decrement in Young's modulus. After the 2 month exposure, Young's modulus from F1 to F3 (5% of masterbatch) and F4 to F6 (3% masterbatch) showed observable increment upon higher PP content. Formulations with higher PP content have slightly higher brittleness for both types of masterbatches as the PP has undergone greater oxidation process which resists the ability to withstand tensile forces which create greater rigidity of the blends, reducing flexibility of PP chain before disintegration of the chain units. The photo-oxidation initially increases the Young's modulus both at the center and surface of the polypropylene composite after exposure with the increase becomes more rapid at the surface of composite film (Wanasekara, 2011).

Thermal properties were determined using DSC characterisations which are melting peak and percent of crystallinity results for unexposed films were tabulated as Table 2. From the result obtained, it is concluded that there is no appreciable difference in melting temperature ~125ºC for each formulation except for F5. The addition of polypropylene composition did not cause any disruption in bonding between crystallites which cause interaction between PE/PP and its additives. Crystallinity of PE/PP was determined based on 100% PE (kJ/mol). The range of crystallinity was found to be in the range between 17% and 26%. PE is a semi crystalline polymer and its crystallinity is low, ~ 20%. The crystallinity of LLDPE used is about 23% and 26% from use of 3% and 5% degradant respectively. The crystallinity is significantly reduced upon blending with PP. A maximum reduction of crystallinity ~26% were obtained for 30% PP with 5% degradant (F3) and 20% PP with 3% degradant (F5). Hence reduction of crystallinity can be brought about by both adjusting the ratio of PP and degradant. PP will contribute to incompatibility to the PE blend although with the use of compatibiliser and this cause the PE to reduce the chain alignment and hence, reduce the blend crystallinity. Reduced amount of degradant also cause disruption in PE chain alignment. This implied that photodegradant have some crystallization initiation by the additive which promote nucleation process. The nuclei grow continuously, forming a stable crystalline phase provided they reach a size greater than a critical nucleus (Chen *et al*. 2001).

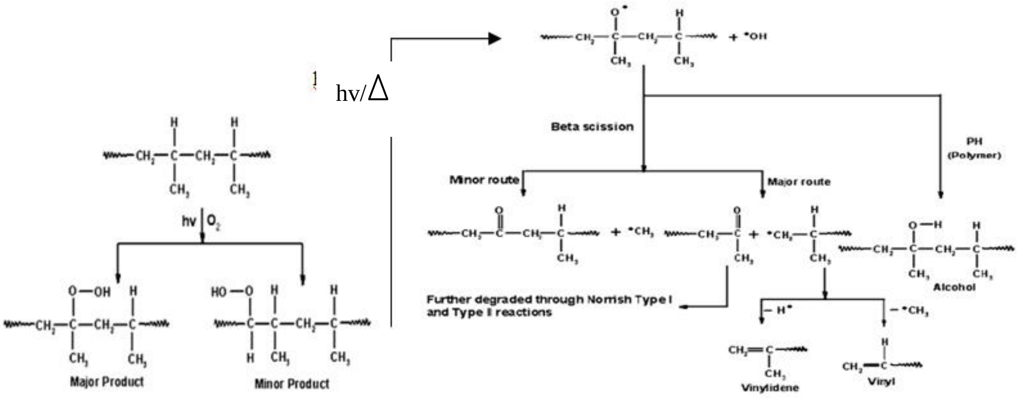

Fig. 4: Formation of carbonyl compound in polypropylene during photo-oxidation (Rajakumar *et al*. 2009)

Conclusion:

The studies proved that addition of PP in PE/PP blends affected the mechanical properties of the product in a way that PP improved the blends' tensile strength before exposure to weathering. Increased use of polypropylene composition in PE/PP blend results in higher tensile properties. The addition of oxidative photodegradant had made polyethylene and polypropylene feasible to degradation with shorter time for example less than 3 months for thin films (< 50 µm). In all, different percentage of photodegradant addition contributed to different effect on samples characteristics upon weathering in spite of no significant effect on the melting temperature analyses. Samples with added photodegradant have showed decreased strength and this suggest that photodegradant is responsible for the phenomena.

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