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RESEARCH ARTICLE

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Mechanical properties of polypropylene biocomposites with sea weeds

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ABSTRACT

The interest in the utilization of bio fillers in thermoplastics has increased recently, mainly due to the need in overcoming the environmental problems caused by the agricultural by products. Based on former exploratory research, we used seaweed fiber as a novel bio filler for the production of polypropylene (PP) biocomposites. Maleic anhydride grafted PP was applied as compatibilizers. The incorporation of the bio fillers at compositions ranging from 10-30% was carried out by melt compounding in extruder and then injection moulded into standard test samples. Mechanical and physical characteristics of the composite systems were studied to evaluate the effect of seaweeds content on PP. It has been found that while there is a decrease in elasticity modulus, tensile strength at break and elongation etc., the hardness and melt flow index were found to be increased with the seaweed content.

1. INTRODUCTION

Polymer/natural fiber biocomposites have recently drawn great attentions in fundamental research and industrial applications for their ecological and economic advantages. Besides environmental concerns, natural fiber reinforced polymer biocomposites provide a unique combination of high performance, great versatility, and processing advantages at favorable costs. Natural lignocellulosic fibers are renewable, completely or partially recyclable and biodegradable; flax, cotton, hemp as well as wood fiber are applied as bio fillers into polymeric matrices [1-4]. Their significant weight saving, low cost and other advantages promote natural fibers as ideal alternative fillers to glass and carbon fibers. Natural fiber biocomposites have already appeared in industrial scale as furniture, household appliances, and as automotive materials [5]. The most important disadvantage of such composite materials is the problem of disposal after end use. This raised the attention of people for the use of natural, sustainable, biodegradable and renewable resources. In modern production environment, there is a great demand for every material to be recyclable or degradable.

Polypropylene is an outstanding commercially available important thermoplastic material with wide range of applications in various fields because of its balanced chemical and mechanical properties [6, 9]. Natural fiber composites, are composite materials i.e., formed by a matrix (resin) and a reinforcement (fiber), in which the fibers are natural i.e., mainly formed by cellulose and therefore originating from plants and bacteria. Some of these fibers can be hemp, jute, flax, sisal, banana, kapok, corn husk etc. [6-10].

Satisfying mechanical properties of different polymer/ natural fiber biocomposites have been reported. Natural fibers have successfully enhanced polymeric matrices with and even without compatibilizers at different natural fiber loadings [11-13]. Thermal properties of

lignocellulosic biocomposites are also of great importance. Remarkable promotion of crystallinity of polymer matrix by natural fibers was reported.

The present work is aimed at the following objectives. To use sea weeds as bio fillers at different composition in polypropylene to get biocomposite and to determine its effect on mechanical, physical and morphological properties of polypropylene bio-composites.

2. EXPERIMENTAL

2.1. Compositions and Materials

Seven different polymer composites were prepared. Compositions of polypropylene/seaweed/maleic anhydride grafted polypropylene (PP/SW/MAPP) polymer composites that were formed are given in Table 1. PP (Moplen EP 3307) supplied by Lyondell Basell. Its density is 0.900 g/cm^3, MFI value is 15 g/10 min (230 ^{o}C, 2,16 Kg) and its head deflection temperature (0.45 MPa, unannealed) is 95.0 ^{o}C. Seaweed was collected from the Cape peninsula coastal region near Cape Town (South Africa) which was washed with water and dried.

2.2. Sample Preparation

The sea weed was washed thoroughly with water to remove the adhered contaminants, and dried in an air oven at 105^{0}C for 24 hours. The size of seaweed particles varied between 30-250 microns. Powder preparation steps are given in Figure 1. Polypropylene, seaweed and maleic anhydride grafted polypropylene were dried overnight at 105 ^{o}C for 24 h in a vacuum oven prior to melt blending. Mechanical premixing of solid compositions was done using a LB-5601 liquid-solids blender (The Patterson-Kelley Co., Inc.USA) brand batch blender for 20 min. Samples with various proportions of PP/SW/MAPP polymer composites were produced between 190-225 ^{o}C at 17 bar pressure, and a rotation rate of 28 rpm, with a Microsan extruder (Microsan Instrument Inc. Turkey). The extruded was cooled and pelletized into granules and dried in vacuum oven at 105 ^{o}C for 24 hours. Subsequently, test samples were manufactured by injection molding. Injection temperature was 190-225 ^{o}C, pressure was 100-120 bar and screw speed was 28 rpm.

Table 1. Composition of the PP/SW/MAPP polymer composites formulations.

Groups	PP (wt %)	Seaweeds (wt %)	MAPP (wt %)
1	100	-	-
2	90	10	-
3	80	20	-
4	70	30	-
5	90	10	5
6	80	20	5
7	70	30	5

waste granulation powder

Figure 1. Seaweed powder preparation steps.

2.3. Test Procedure

The elasticity modulus, yield strength, tensile strength at break and % elongation of the compressed plates were measured by using a tensile testing machine (Zwick Z010, Germany) according to ASTM D638 at room temperature and crosshead speed of 50 mm/min. For every composition, seven samples were tested. The hardness test was done according to the ASTM D2240 method with Zwick hardness tester. To investigate fracture behavior, Izod impact test (notched) was done at room temperature according to the ASTM D256 method with Zwick B5113 impact tester (Zwick, Germany). Heat deflection temperature (HDT) and Vicat softening point tests were done according to ISO 75 and ISO 307 standard with determined by CEAST 6521. HDT-Vicat test equipment. Flow behavior testing of all the mixtures was done according to ISO 1133 standard with Zwick 4100 MFI equipment. The fractured surfaces of the PP/SW/MAPP polymer composites were coated to thickness of 20 Å of a gold (Au) to prevent electrical charging by Polaron SC7640 (high resolution sputter coater) (United Kingdom). The surfaces of the prepared samples were observed by the FEI Sirion XL30 FEG (Nederland) scanning electron microscopy (SEM) at an acceleration voltage of 10 and 20 kV.

3. RESULT AND DISCUSSION

3.1. Mechanical properties of seaweed filled PP

The relationship between the elasticity modulus and the percentage of the seaweed of PP composites is shown in the Figure 2-A. With inclusion of seaweed particles in the polymer matrix the elasticity modulus of the composite is found to be decreasing. For example, the elasticity modulus of the three different samples (with 10, 20, and 30 wt% of seaweed, without MAPP) is measured as 571, 530, and 424 MPa respectively. The elasticity modulus of pure PP is 550 MPa. In comparison with the elasticity modulus of virgin PP, the elasticity modulus decreased by 23% for the composites with a 30 wt % seaweed concentration. On the other hand, the elasticity modulus of the three different samples (with 10, 20, and 30 wt% of seaweed, with 5% MAPP) is measured as 545, 512, and 396 MPa respectively. In comparison with the elasticity modulus of virgin PP, the elasticity modulus decreased by 23% for the composites with a 30 wt % seaweed concentration. MAPP addition reduced elastic modulus value, possibly due to poor compatibilisation of seaweeds in the PP matrix.

N. Jaya Chitra et al. [14] investigated polypropylene/seaweed biocomposites and they found similar results. For example, tensile modulus of biocomposites decreased with increasing seaweed rate. The relationship between the yield strength and the percentage of the seaweed of PP composites is shown in the Figure 2-B. With inclusion of seaweed particles in the polymer matrix the yield strength of the composite is found to be decreasing. For example, the yield strength of the three different samples (with 10, 20, and 30 wt% of seaweed, without MAPP) is measured as 22, 21, and 18 MPa respectively. The yield strength of pure PP is 29 MPa. In comparison with the yield strength of virgin PP, the yield strength decreased by 40% for the composites with a 30 wt % seaweed concentration. On the other hand, the yield strength of the three different samples (with 10, 20, and 30 wt% of seaweed, with 5% MAPP) is measured as 23, 22, and 22 MPa respectively. In comparison with the yield strength of virgin PP, the yield strength decreased by 24% for the composites with a 30 wt % seaweed concentration. The relationship between the tensile strength at break and the percentage of the seaweed of PP composites is shown in the Figure 2-C. With inclusion of seaweed particles in the polymer matrix the tensile strength at break of the composite is found to be decreasing. For example, the tensile strength at break of the three different samples (with 10, 20, and 30 wt% of seaweed, without MAPP) is measured as 14, 13, and 12 MPa respectively. The tensile strength at break of pure PP is 19 MPa. In comparison with the tensile strength at break of virgin PP, the tensile strength at break decreased by 37% for the composites with a 30 wt % seaweed concentration. On the other hand, the tensile strength at break of the three different samples (with 10, 20, and 30 wt% of seaweed, with 5% MAPP) is measured as 16, 14, and 13.5 MPa respectively. In comparison with the tensile

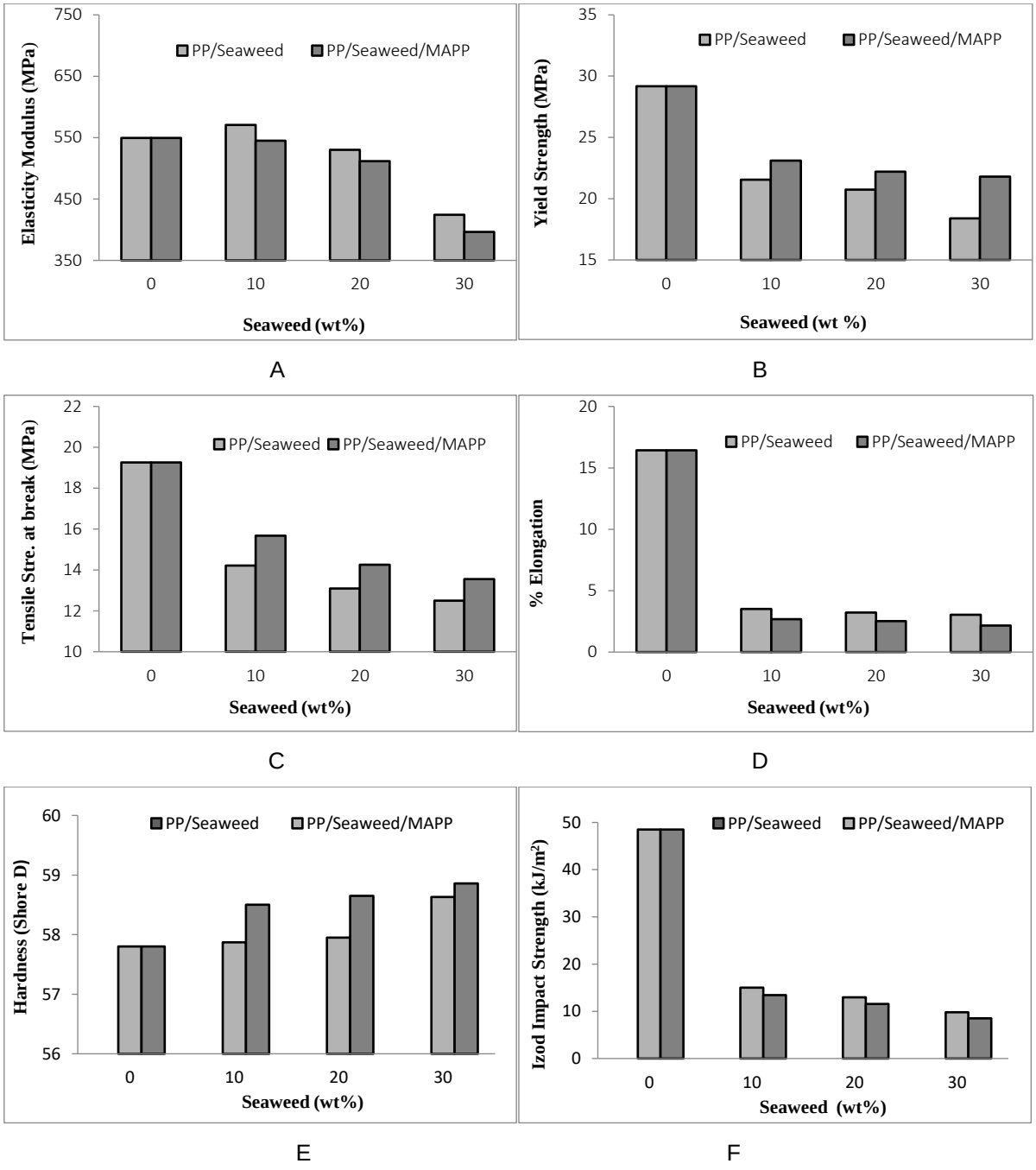

Figure 2. Mechanical properties of PP/SW/MAPP polymer composites.

strength at break of virgin PP, the tensile strength at break decreased by 31% for the composites with a 30 wt % seaweed concentration. Lixing Luan et al. [15] investigated polypropylene/seaweed biocomposites and they found similar results. For example, tensile strength at break values of biocomposites decreased with increasing seaweed rate. N. Jaya Chitra et al. [14] investigated polypropylene/seaweed biocomposites and they found similar results. For example, tensile strength

at break values of biocomposites decreased with increasing seaweed rate. The relationship between the % elongation and the percentage of the seaweed of PP composites is shown in the Figure 2-D. With inclusion of seaweed particles in the polymer matrix the % elongation of the composite is found to be decreasing. The % elongation of the three different samples (with 10, 20, and 30 wt% of seaweed, without MAPP) is measured as 4, 3, and 3 % respectively. The % elongation of pure PP is 16 %. In comparison with the % elongation of virgin PP, the % elongation decreased by 81% for the composites with a 30 wt % seaweed concentration. On the other hand, the % elongation of the three different samples (with 10, 20, and 30 wt% of seaweed, with 5% MAPP) is measured as 3, 2.5, and 2 % respectively. In comparison with the % elongation of virgin PP, the % elongation decreased by 87.5% for the composites with a 30 wt % seaweed concentration. N. Jaya Chitra et al. [14] investigated polypropylene/seaweed biocomposites and they found similar results. For example, % elongation values of biocomposites decreased with increasing seaweed rate. The relationship between the hardness and the percentage of the seaweed of PP composites is shown in the Figure 2-E. With inclusion of seaweed particles in the polymer matrix the hardness of the composite is found to be a little increasing. For example, the hardness of the three different samples (with 10, 20, and 30 wt% of seaweed, without MAPP) is measured as 57.87, 57.95, and 58.63 Shore D respectively. The hardness of pure PP is 57.8 Shore D. In comparison with the hardness of virgin PP, the hardness increased by 1.4% for the composites with a 30 wt % seaweed concentration. On the other hand, the hardness of the three different samples (with 10, 20, and 30 wt% of seaweed, with 5% MAPP) is measured as 58.5, 58.65, and 58.86 Shore D respectively. In comparison with the hardness of virgin PP, the hardness increased by 1.7% for the composites with a 30 wt % seaweed concentration. The relationship between the Izod impact strength and the percentage of the seaweed of PP composites is shown in the Figure 2-F. With inclusion of seaweed particles in the polymer matrix the Izod impact strength of the composite is found to be decreasing. For example, the Izod impact strength of the three different samples (with 10, 20, and 30 wt% of seaweed, without MAPP) is measured as 15, 12.96, and 9.8 kJ/m^2 respectively. The Izod impact strength of pure PP is 48.48 kJ/m^2. In comparison with the Izod impact strength of virgin PP, the Izod impact strength decreased by 79% for the composites with a 30 wt % seaweed concentration. On the other hand, the Izod impact strength of the three different samples (with 10, 20, and 30 wt% of seaweed, with 5% MAPP) is measured as 13.45, 11.53, and 8.54 kJ/m^2 respectively. In comparison with the Izod impact strength of virgin PP, the Izod impact strength decreased by 82% for the composites with a 30 wt % seaweed concentration.

3.2 Physical properties of the seaweed filled PP

The relationship between the Vicat softening point and the percentage of the seaweed of PP composites is shown in the Figure 3-A. With inclusion of seaweed particles in the polymer matrix the Vicat softening point of the composite is found to be decreasing. For example, the Vicat softening point of the three different samples (with 10, 20, and 30 wt% of seaweed, without MAPP) is measured as 131, 126, and 119 ^{o}C respectively. The Vicat softening point of pure PP is 134 ^{o}C. In comparison with the Vicat softening point of virgin PP, the Vicat softening point decreased by 11% for the composites with a 30 wt % seaweed concentration. On the other hand, the Vicat softening point of the three different samples (with 10, 20, and 30 wt% of seaweed, with 5% MAPP) is measured as 133.5, 130.7, and 122.6 ^{o}C respectively. In comparison with the Vicat softening point of virgin PP, the Vicat softening point decreased by 8.5% for the composites with a 30 wt % seaweed concentration. MAPP addition reduced Vicat softening point value. The relationship between the HDT and the percentage of the seaweed of PP composites is shown in the Figure 3-B. With inclusion of seaweed particles in the polymer matrix the HDT of the composite is found to be decreasing.

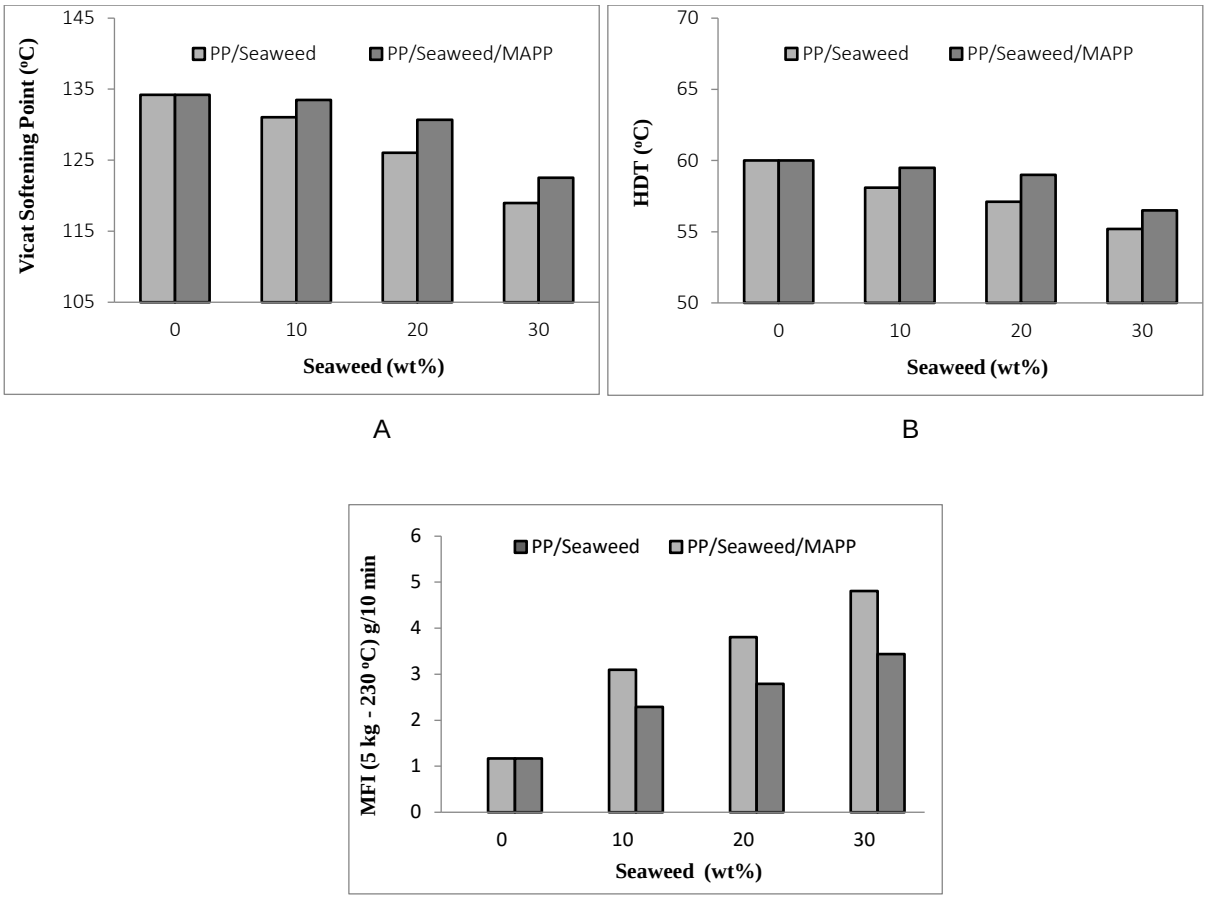

Figure 3. Physical properties of PP/SW/MAPP polymer composites.

For example, the HDT of the three different samples (with 10, 20, and 30 wt% of seaweed, without MAPP) is measured as 58.1, 57.1, and 55.2 °C respectively. The HDT of pure PP is 60 °C. In comparison with the HDT of virgin PP, the HDT decreased by 8% for the composites with a 30 wt % seaweed concentration. On the other hand, the HDT of the three different samples (with 10, 20, and 30 wt% of seaweed, with 5% MAPP) is measured as 59.5, 59, and 56.5 °C respectively. In comparison with the HDT of virgin PP, the HDT decreased by 5.8% for the composites with a 30 wt % seaweed concentration. The relationship between the MFI and the percentage of the seaweed of PP composites is shown in the Figure 3-C. With inclusion of seaweed particles in the polymer matrix the MFI of the composite is found to be increasing. For example, the MFI of the three different samples (with 10, 20, and 30 wt% of seaweed, without MAPP) is measured as 3.1, 3.8, and 4.8 g/10 min respectively. The MFI of pure PP is 1.2 g/10 min. In comparison with the MFI of virgin PP, the MFI increased by 300% for the composites with a 30 wt % seaweed concentration. On the other hand, the MFI of the three different samples (with 10, 20, and 30 wt% of seaweed, with 5% MAPP) is measured as 2.3, 2.8, and 3.4 g/10 min respectively. In comparison with the MFI of virgin PP, the MFI increased by 183% for the composites with a 30 wt % seaweed concentration.

3.3 Morphological properties of the seaweed filled PP

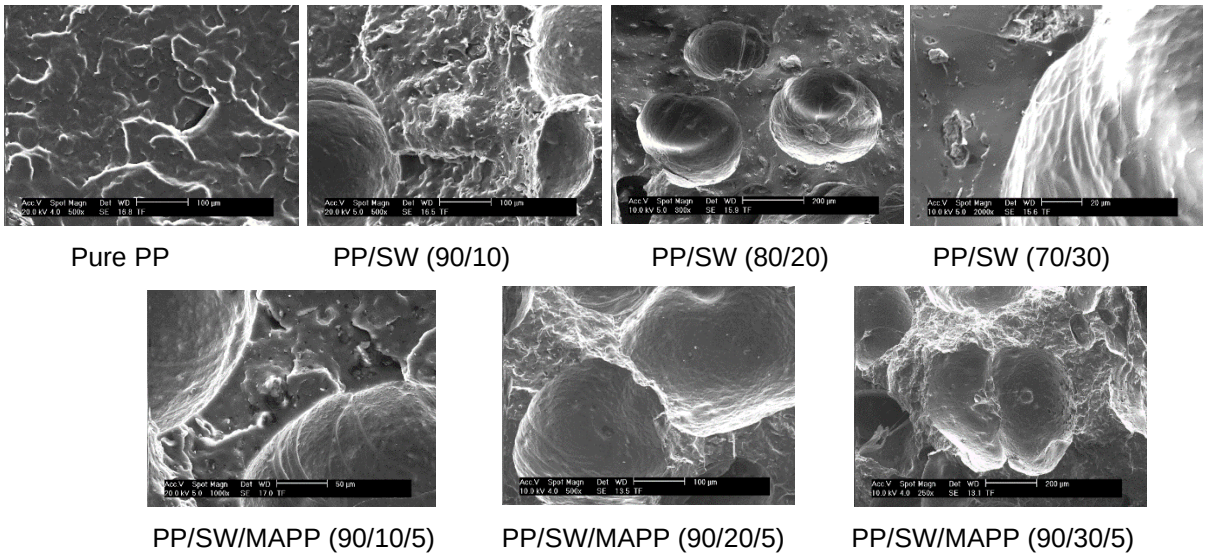

Figure 4. SEM photographs of PP/SW/MAPP polymer composites.

The SEM study was carried out to study the dispersion of SW in the PP matrix. Scanning electron microscopic observation is considered as an effective method for accessing visibility between the components in a polymer blend. The boundaries and the contrast can be obviously seen between the SW and PP matrix on the fractured surfaces of polymer matrix (Figure 4). The micrographs indicate that the all SW particulates are homogeneously dispersed on the fractured surfaces of polymer matrix.

4. CONCLUSIONS

The effects of seaweed and maleic anhydride grafted PP on the some properties, the elastic modulus, yields strengths, tensile strengths, % elongation, hardness, Izod impact resistance, Vicat softening point, HDT, MFI and morphological of PP/SW/MAPP composites were investigated. Seaweed a waste can be used as a potential filler material in polypropylene matrix composites. It has effects on the mechanical properties of the composites. The following results were obtained: The elasticity modulus, yield strength, tensile strength at break and % elongation of PP/SW/MAPP composites decreased as the seaweed concentration increases. The hardness of PP just a little increased as the seaweed concentration increases from 0 to 30 wt %. On the other hand, Izod impact strength of composites decreased as the seaweed concentration increases from 0 to 30 wt %. The micrographs indicate that the seaweed particulates are homogeneously dispersed on the fractured surfaces of PP matrix.

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