

The effect of a dispersing agent on the properties of polypropylene composites with seaweed fillers

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Abstract

The main focus of this work is to study the processability and characteristics of highly algae-loaded thermoplastic polymer composites. The seaweed powder was characterized in terms of morphology. Polymer/Alg composites were prepared by extrusion compounding. Polypropylene (PP) was used as the polymer matrix. During extrusion mixing, the composites were injection molded and characterized for their structural, morphological, and mechanical properties to determine the effect of the dispersant agent. The results for this research work has shown that algae can be used as a filler in the preparation of composites and that it is possible to play on the rate of the charge and of the dispersing agent to improve certain targeted properties for any specific application

Keywords: seaweed powder; Polymer-matrix composites; Polypropylene Mechanical properties; chemical treatment.

I. Introduction

Composite materials are those materials which built from two or more constituent materials with considerably different physical or chemical properties that when joined, to develop composite. Composite materials depend on the properties of constituent materials, the fibers and the resin used [1]. At present days, the advance composite material has been broadly used composite in the engineering field due to their noble mechanical properties. Advantages of this like as corrosion resistance, electrical insulation, more stiffness and strength, fatigue resistance, lesser in weight than metal, easy process ability at less energy requirement in tooling and assembly costs widely acceptable in structure applications [2].

Lots of advanced research literature is mentioned on composites reinforced with natural fibers so as to refine the mechanical resistance and mark them appropriate in many engineering applications [3].

Natural fibers are cheap, eco-friendly, lightweight, as well as competitive with synthetic material regarding material properties. To increase the performance of the bio-based fiber composite the raw material such as fiber and matrix material are chemically or physically modified [4].

Indeed, proper interfaces assure the transfer of load from the matrix to the stiff fibers. Wherefore, weak interaction notably drops the mechanical properties of the composite materials [5,6]. The compatibility and wettability between natural fibers and polymers can be improved by adding coupling and dispersing agents [7]. The treatment not merely enhances interfacial adhesion, but also provides better fibers dispersion [8]. Chemical treatments have been postulated as methods to improve the performance of biocomposite materials by enhancing the interaction of NFs with the polymeric matrix. The interaction is improved when undesirable organic components are removed and the functionality of cellulosic components on the fiber is modified [9,10]. Sobczak et al. reviewed the physical and chemical treatments to improve the interaction between natural fibers and the polymer matrix interface. These strategies lead to an increase in the capability for stress transfer at the interface [11]. Dispersants and coupling agents supply several advantages and are chosen based upon the application requirement. Dispersants adhere to the fiber surface but without a strong link with the matrix. Coupling agents also adhere to the fiber as well to the polymer through chemical bonds or through chain entanglement. Thus, the dispersant role

is to foster the homogeneity and limit defect sites by means of the agglomerate to give better dispersion of the fibers. Dispersants are a surface-active agent, being composed of two segments chemically different [12]. For this purpose, a dispersing agent It was applied in the current work BYK-W 980. It was a composite made of PP and seaweed powder. Study of mechanical and morphological properties of the compounds obtained in order to see the effectiveness of the dispersant on the PP/Alg compounds.

II. Experimental

II.1. Material

Commercial grade of polypropylene ISPLEN PP 040 C1E, supplied by REPSOL, with a melt index of 3.0 g/10 min (at 230 °C), were used as the matrix. Pickled seaweed was collected from the rocks of AINBINIANE ALGIERS.

The algae were initially washed with distilled water to remove dust and other waste then dried at room temperature for about a week. Then, they were dried in an oven at 40°C for about 48 hours and stored in closed containers. In order to obtain the seaweed flour, they are finely fractionated in a grinder (RestschZM200) with an ultra-centrifugal rotor at high speed, and then sassed using a 0.02 µm sieve. Methanol was 99% pure purchased from Changshu Yangyuan Chemical Company (Jiansu, China). The dispersing agent has been kindly given by **BYK-CHEMIE** whose properties are Trade Name: **BYK-W 980**.

Chemical nature Composition: Solution of a salt of unsaturated polyamine amides and acidic polyesters.

Acid value (mg KOH/g) = 129.

II.2. Seaweed fiber treatment

Due to the hydrophilic character of natural fibers, they are considered incompatible with the hydrophobic polymer matrix and for this reason we have resorted to chemical treatment. In fact, the esparto fiber has been treated with a dispersing agent: BYK W-980. This chemical modification was carried out according to the following Protocol: 30g of esparto fiber was immersed in 100ml of methanol in a beaker with (2 pigs) by weight of dispersing agent, under stirring with a mechanical stirrer for one hour at room temperature. At the end of the reaction, the mixture was filtered and washed three times with acetone to remove excess reagent.

II.3. Preparation of composites

The composite preparation process is as follows: the required quantities of raw materials such as PP, filler (processed and unprocessed) were loaded into the extruder. The mixture was

mixed using a twin screw extruder with a rotor speed of 80 rpm ; and the temperature of the extrusion operation was maintained in the range of 190 to 230°C. The extruded product was then cut into pellets and dried at room temperature. Then, the pellets were passed through an injection molding machine (Japan Steel Works, India) set at 190–210°C, 100 rpm and a holding pressure of 300 bar. Pellets were molded into conventional shapes and cooled to room temperature for testing and characterization. A reference sample of PP was also prepared in a similar manner.

II.4. Characterization

II.4.1. Fourier-transform infrared spectroscopy (FTIR)

The samples were dried at 80 °C for one hour and used for infrared spectroscopy analysis. Infrared measurements were made on an FTIR spectrophotometer (SHIMADZU FTIR-8400S). A resolution of 4 cm⁻¹ was used in the 4000-400 cm⁻¹ wavenumber region.

II.4.2. Optical microscopy

The PP et PP/alg composites were imaged by Lecia DCM8 optical microscopy full version of 3D surface metrology. The samples were placed at the level of fracture and the results were obtained in the form of images.

II.4.3. Mechanical properties

Tensile properties were obtained at room temperature according to ASTM D638 and using the universal test machine Instron 5969 equipped with an SVE 2 Non-Contacting Video Extensometer. The cross-head speed was fixed at 5 mm/min using a 50 kN load cell. For each material, six different specimens were subjected to tensile tests and average values of tensile strength, Young's modulus and elongation at break were calculated.

III. Results and discussion

III.1. Fourier Transform Infrared Spectroscopy (FTIR)

Fig.1 shows the FT-IR (a) spectra of the neat Alg and Alg/BYK W-980 ; The main changes in the spectrum of untreated algae compared to that of BYK W-980 treated algae are as follows :

A reduction in the intensity of the band at 3408 cm⁻¹ corresponding to the OH groups is observed, this reduction is due to the reduction of the hydrophilic character of the charge.

A band of average intensity towards 2927 cm⁻¹ translates the vibrations of elongations of the bonds C-

H of the group -CH and CH₂.

Appearance of an absorption band at 1743 cm⁻¹, this band corresponds to the elongation vibration of the C=O bond of the ester function existing in the charge. Decrease of the bands at 1627 cm⁻¹ corresponding to the deformation (H-O-H) of the water absorbed by the charge following the chemical treatments.

The broad bands in the region of 500-700 cm⁻¹ are due to residual water in the algae.

In parallel the spectrum of PP clearly illustrates the symmetric and asymmetric elongation vibrations of the C-H bonds of the aliphatic -CH₂ group and the CH₃ groups in the range between 2975 and 2840 cm⁻¹ and the symmetric deformation vibration of the -CH₂ group around 1464 cm⁻¹ (fig 1 (b)). The band around 1370 cm⁻¹ is characteristic of the symmetric deformation of the CH₃ groups at the end of the chains. An intense band is visualized around 820 cm⁻¹ and is characteristic of the balancing of the methylene groups - (CH₂-) - when nis greater than 4 (-CH₂-polymeric) [13].

Also, we notice that the FTIR spectrum of PP/Alg and PP/Alg/BYK W-980 is identical to that of PP but it reveals, in addition to the absorptions of PP, a characteristic band of the carbonyl group of the alga in the range [1580,1740] cm⁻¹ This is synonymous with the grafting of the filler onto the PP chains. With an increase in intensity of the bands at 1627 cm⁻¹ and 500-700 cm⁻¹ of PP/Alg/PYK W-980 by a for PP/Alg This is explained by the effect of chemical treatment by the dispersing agent and the filler/dispersing agent complex is well bound to the matrix [14].

It is noticed that the band around 2927 cm⁻¹ of the filler is dispersing and this reflects the elongation vibrations of the C-H bonds of the -CH and CH₂ group, which is synonymous with the grafting of the filler onto the PP chains.

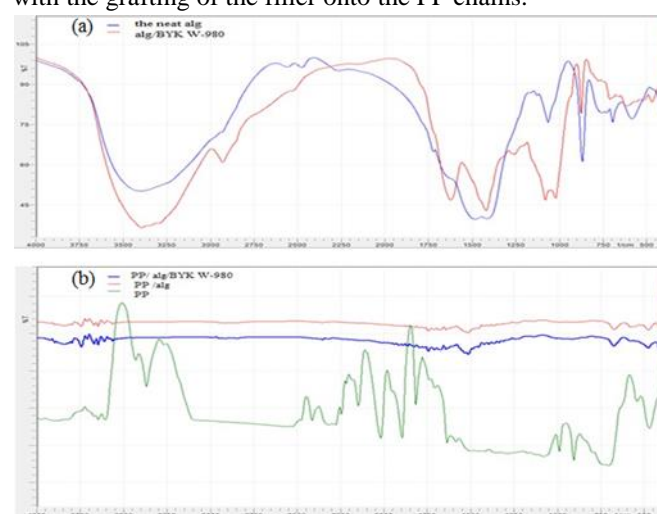


Figure 1. FTIR spectra : a) the neat Alg and alg/BYK ; b) the PP, PP /Alg and PP/ Alg/BYK W-980

III.2. Optical microscopy

To investigate the phase morphology of PP/Alg (b), PP/Alg /BYK W-980 (c) and virgin PP (a), fracture surfaces at room temperature of the samples were observed by optical microscope after being gold coated (Fig. 2). It is clear that there are surface morphology distinctions between the different samples, as shown in (Fig.2). A visual aspect we observe the change of color in the case of the composite by to for to virgin pp due to add load. Seaweed occurs as flat, brittle flakes. The particle size distribution before and after sorting and mixing with PP will be discussed in the breaking section of sorted PP/Alg composites and unsorted PP/Alg composites sorted by to for the breaking section of virgin PP. for all samples have an irregular surface (Fig.2). In the case of composites filled with raw algae, it is noticed that the fibers detach and are taken from the PP matrix. As shown in photo (b) of Figure 2, the surfaces of the fibers are smooth and clean, which shows the weak interfacial adhesion between the fibers and the matrix with the presence of the aggregates of different sizes form on the surface of the PP. The photos show the presence of several knots. However, no clear gap is observed in the interfacial region between the PP matrix and the algal fiber for the PP/Alg/BYK W-980 systems photo (c) of Fig 2. Algae treated with BYK w-980 (Fig.2) are coated with layers of matrix material which significantly reduce the differences between them. This is probably due to the wetting of the algae by the dispersing agent which reduced the contrast between the fibers and the PP. These results are in agreement with previous studies which confirmed that the treatment with the dispersing agent BYK w- 980 of the natural fibers used as reinforcements, improves the cohesion between the fibers and the matrix of the corresponding composite materials [15]. That change in morphology is an indication of improvement in PP/Alg miscibility of the mixture after addition of the dispersing agent incorporation of algae.

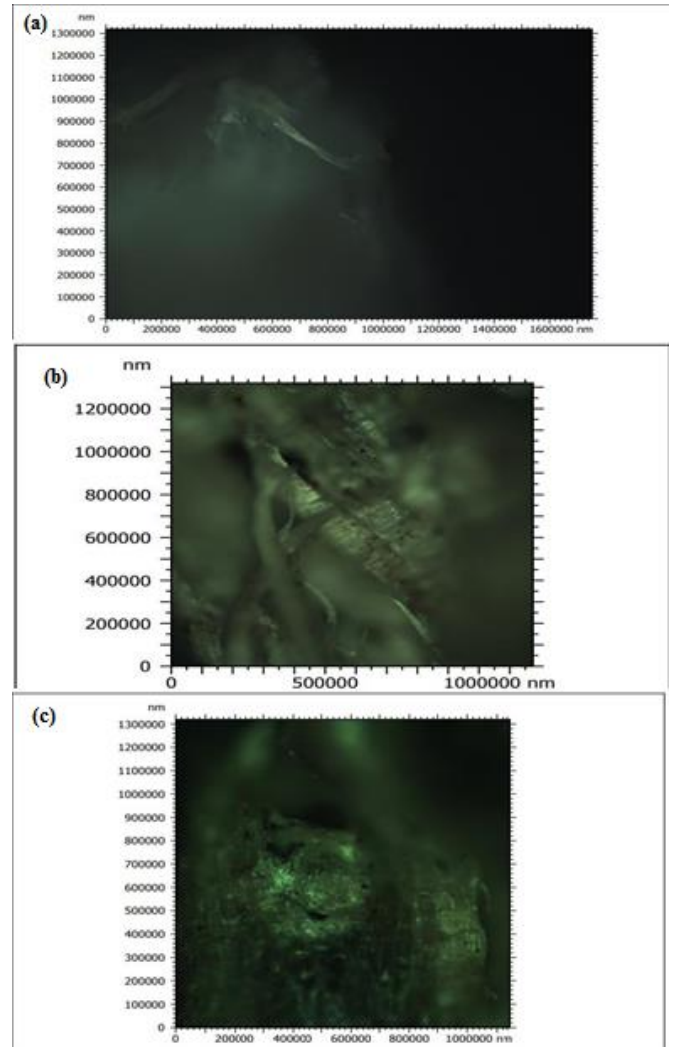


Figure 2. Optical microscope micrographs of the fracture surface of a PP (a), (b) PP/Alg, PP/Alg /BYK-980.

III.3. Mechanical properties

To reveal the effect of loads and treatment on mechanical properties such as tensile strength, elongation at break of PP/Alg mixture, tensile tests were carried out and the results are shown in (Fig 3). Tensile strength (TS) and elongation at break (EAB) of the composites based on PP loaded with treated and untreated seaweed and virgin PP. According to number tensile results the strength of the composite reflects a considerable loss when adding seaweed fiber in PP matrix. Indeed, we are registering a drop compared to virgin PP. This is explained by poor dispersion of the algae fiber in the polymer which caused a weakening of the interfacial adhesion of the constituents of the composite increasing; therefore the transfer of constraints is not guaranteed. When BYK W-980 dispersant was added to (PP/Alg) composites, the Tensile strength (TS) and elongation at breaking (EAB) have been significantly improved. This significant improvement in tensile strength is generally attributed to better interfacial interaction and adhesion between the fibers and the polymer, leading to a better transfer of the stresses of

the fiber matrix, the incorporation of the loading with treatment implied a positive effect on the tensile strength and the elongation at break. Similar results have also been demonstrated by other authors for other polymers reinforced with natural fillers [16]. This increase indicates that the composite stiffness is increased. The stiffness and good dispersion of the fibers after processing result in interaction changes and chain mobility. Thus, the use of dispersing agent improves the dispersion state of the rigid fiber which prevents the movement of the continuous PP and increases the tensile strength which is decreased elasticity consequently the elongation at break increases. Finally, these results showed that the mechanical properties are in agreement with the morphological and structural results.

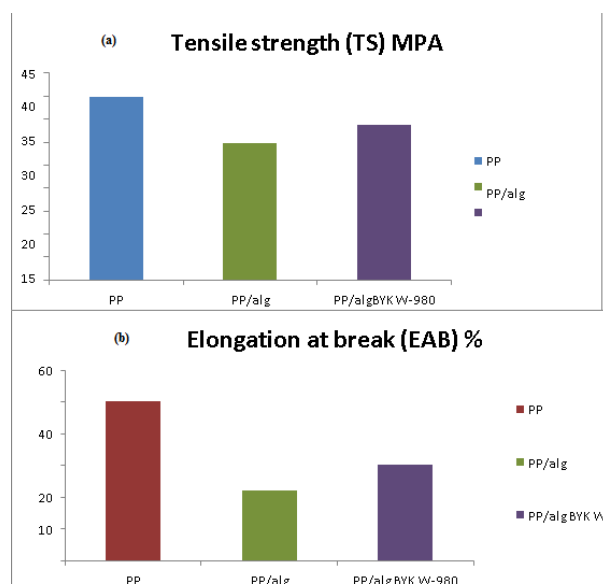


Figure 3. Tensile strength (TS) (a) and elongation at break (EAB) (b) of the composites based on PP loaded with treated and untreated seaweed and virgin PP.

IV. Conclusions

A PP matrix, untreated and W-980 dispersing agent treated algal fibers were used to develop composites. Mechanical, optical and structural properties were studied and compared.

Infrared results showed that the structure of the algae changed after the treatment process. This change was shown by the decrease of the peak at 3408 cm^{-1} after the treatment corresponding to the -OH group.

Optical microscopy shows that the treatment improved the dispersion of the alga in the PP matrix, as well as the interfacial adhesion.

The mechanical properties were studied by the tensile test. This study reveals that the incorporation of seaweed powder into the PP matrix increases the

stiffness of the composites as well as the stress and elongation at break increase after the treatment compared to pure PP and PP/alg.

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