Journal of Alasmarya University: Basic and Applied Sciences
Vol. 6, No. 5, December 2021, Special Issue for Forth Conference on Engineering Science and Technology (CEST-2021)
مجلة الجامعة الأسمرية: العلوم الأساسية والتطبيقية
المجلد 6 ،العدد 5، ديسمبر 2021، عدد خاص بالمؤتمر الرابع للعلوم الهندسية والتقنية (CEST-2021)

Low and High Molecular Weight Polyethylene Glycol as A Treating and Coupling Agent in High Density Polyethylene/Date Palm Tree Fiber Composites

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ABSTRACT

The mechanical properties and water absorption (WA) behavior of high density polyethylene/date palm tree fiber (HDPE/DPTF) composites were investigated. Two different parts of the date palm tree (mesh and leaflets) were used. The focus was on studding the combination effect of using both low and/or high molecular weight polyethylene glycol (PEG) as a treatment and coupling agent, respectively on shore D hardness, impact strength and water absorption behavior of the composites. Morphological properties of the prepared composites were also investigated. Results showed that treating the fibers with low molecular weight PEG had a significant effect, which resulted in composites with better shore D hardness and impact strength compared to pure HDPE and composites made with untreated fibers. Furthermore, the use of high molecular weight PEG as a coupling agent resulted in better impact strength and shore D hardness, indicating the presence of a strong interaction between the fibers and the HDPE matrix. Morphological observations of composites made with untreated fibers by scanning electron microscope (SEM) revealed the formation of some fiber aggregation, fiber debonding and fiber pullout in composites made with untreated fibers. Contrary, the composites made with PEG as a treatment and/or coupling agent showed no fiber aggregation or fiber debonding.

Keywords:
Date palm tree fiber.
High density. Polyethylene.
Mechanical properties.
Polyethylene glycol.

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1 INTRODUCTION

In the last decade, natural fibers (NFs) have attracted the attention of many researchers as an alternative to conventional fillers such as glass, carbon and synthetic fibers in the reinforcement of polymer composites (PCs) [1,2]. This can be mainly attributed to their advantageous properties over other fillers such as low energy consumption, non-abrasive nature, low cost, renewability, biodegradability, easy availability, and worldwide abundance [3]. NFs reinforced polymer composites (NFRPCs) represent an emerging class of materials that combine the best properties of both NFs and polymers. In most cases, the obtained NFRPC materials have improved properties, which widens their structural applications [4]. NFs are generally extracted out of plants, animals and mineral sources. However, plant fibers are inexpensive, renewable and biodegradable, which are mainly sourced from the leaves, stems and seeds of a variety of plants, such as sisal, bamboo, coconut, jute, flax, hemp, kenaf, coir, kapok, palm, banana, etc. [5, 6]. Plant fibers are mainly composed of cellulose, hemicelluloses, lignin, waxes, and several water-soluble compounds [7, 8]. Commonly, there are two types of polymers used as a matrix for the production of NFRPCs, namely thermoplastics (such as low density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), poly vinyl chloride (PVC), nylon, and acrylics) and thermosets (epoxies, polyesters, and phenolics) [3,9]. Polyolefin blends [10] and copolymers [11, 12] are also used as a matrix to obtain NFRPCs.

Date palm trees, which are widely grown in Libya and nearby countries in North Africa and the Middle East) can be considered as one of the main sources of NFs. These date palm tree fibers (DPTFs) could be extracted from different parts of the date palm trees, namely: the midribs, spadix stems, leaflets, and meshes [13]. Despite some traditional uses of date palm tree products in Libya to make ropes, baskets and other products, a substantial amount of date palm tree parts end up as a waste material from the agriculture sector. Row DPTFs are hydrophilic lightweight fibers that are easy-to-obtain at low-cost and possess good durability that withstand well against deterioration [14]. Thus, DPTFs would be a good reinforcing filler for polymers, which can be of great interest to researchers and scientists in the area of polymer composites [11,15]. It has been shown that, these fibers can improve the compressive strength and general strength of soil composite materials as they lock and unite individual particles and collections of particles together [16]. According to many studies [17-19], palm fibers have been shown to be very effective reinforcing filler in both thermosetting and thermoplastics. Other studies showed that, composites made of palm fibers have moderate tensile and flexural properties compared with composites containing other NFs such as grass reeds, kenaf, ramie, sisal, coir, banana fiber…etc [11]. This might be attributed to the fact that palm fibers have the highest cellulosic content (nearly 50%) as compared to other NFs [20]. This might be also due to the low bulk density of DPTF compared to other NFs [21]. Furthermore, polymer composites reinforced with palm tree fiber have been reported to be very suitable for many components, which are used in the automotive industry [18-20].

Like other NFs, DPTF has to be pretreated to improve their moisture repellency and resistance to environmental effects, consequently improving their mechanical properties. Moreover, in order to improve the interfacial interaction between polymer molecules such as polyolefins (i.e., LDPE, HDPE, PP, etc.) and NFs, surface modification of the fibers and/or the addition of a suitable coupling agent is required [22]. In this regard, NFs can be treated with various chemicals such as alkali, silane, peroxides, permanganates and polyethylene glycol (PEG) [23]. PEGs are available in a wide range of molecular weights, ranging from liquids at room temperature (PEG 200-600), semisolids (PEG 1470), semi-crystalline solids (PEG 3000-20000 and above) to resinous solids with very higher molecular weights (>100000) [24]. According to Luo et. al. [25] modification of wood flour (WF) with PEG might lead to a reduction in interfacial compatibility between the wood and polymer matrix. They also concluded that PEG modification in general reduced the water uptake, thickness swelling, shrinkage and swelling. Moreover, PEG treatment of WF remarkably improved the dimensional stability of the composites. This was attributed to the fact that PEG can penetrate wood tissues, replace water molecules, and reinforce its structure, thus improving its dimensional stability [26]. Tajeddin et al. [27] found that the effect of PEG (low molecular weight of 400 - 600) treatment on the heat-tolerance of biocomposites made from LDPE and wheat straw were greater than that of PE-grafted maleic anhydride. It has been also shown [28] that the processability and melt flow ability of composites made with bamboo fiber and polylactic acid was improved with the addition of high molecular weight PEG (molecular weight of 20000). Results obtained by Tajeddin et al. [29] illustrated that the thermal stability of LDPE filled with kenaf fiber can be improved by using PEG (high molecular weight of 8000) as a coupling agent. In other study Tajeddin et.al. [30] also found that good homogeneity between LDPE or HDPE with cellulose composites can be obtained by the addition of PEG (high molecular weight of 8000) in order to find reasonable and acceptable properties.

From the open literature discussed above, one can conclude that PEG has been used either as a treatment agent or as coupling agent. In this study, low molecular weight PEG was used to treat the DPTFs while high molecular weight PEG was used as a coupling agent. Adding low molecular weight only will not enough to decrease the hydrophilic character of the palm fiber (not compatible with most polymers) by blocking or modifying their hydroxyl groups.to make them more compatible with polymer molecules, high molecular weight PEG (hydrophobic) must be used. We hypothesize that this will have a positive effect on the physical and mechanical properties of HDPE/DPTF composites as compared to pure HDPE. To the best of our knowledge, this is the first report on the combined use of two different PEG with different molecular weight to make polymer/palm tree fiber composites.

2 EXPERIMENTAL PART

2.1 MATERIALS

Date palm tree (mesh and leaflets) were used as filler materials, which were obtained from Al-Grabolli city, Libya. They were first washed with tap water to remove any contaminants, adhering dirt and dust. The mesh and leaflets were then air dried at room temperature for 48 h. Subsequently, they were grinded and sieved to obtain DPTFs with sizes ranging from 38 to 150μm. HDPE obtained from Saudi Basic Industries Corporation (SABIC) was used as the matrix for all composites (HDPE F00952, Melt flow index (MFI) = 0.05 g/10 min (ISO 1133, 190 °C, 2.16 Kg), density = 952 g/cm3 (ISO 1183)). PEG (Alfa Aesar, UK) with weight average molecular weight of 400 g/mole (PEG400) in liquid form was used to modify the mesh and leaflet fibers. PEG (Alfa Aesar, UK) with weight average molecular weight of 6000 g/mole (PEG6000) in solid form was used as a coupling agent.

2.2 TREATMENT OF DPTFS WITH LOW MOLECULAR WEIGHT PEG

The dry DPTFs were stirred in 30% PEG400 solution at 100 °C for 2h in a reflux system. The fibers were then removed from the solution, washed with distilled water to remove the excess PEG, and then oven-dried at 80 °C for 24 h.

2.3 PREPARATION OF HDPE/DPTF COMPOSITES

The DPTFs (obtain from the mesh and leaflets) were dried in an oven for about 4 h at 80 °C, after which they were mixed with solid PEG6000 to provide a homogeneous mixture. The mixture was then mixed using twin screw extruder (Brabender, Germany) (L/D ratio of 48) with screw speed of 70 r.p.m. at 140 ^{o}C. The same process was used to prepare composites with untreated DPTFs (mesh and leaflets) without the addition of PEG6000. The obtained composites were subsequently cooled in the air for 24h and then cut into small pieces. Details of the composites and their codes are reported in Table 1.

Table 1: Composite compositions and their codes.

Composite code	HDPE (wt%)	Untreated DPTFs obtained from mesh (wt%)	Treated DPTFs obtained from mesh (wt%)	Untreated DPTFs obtained from leaflets (wt%)	Treated DPTFs obtained from leaflet (wt%)	PEG6000 (wt%)
F0/L0	100	0.0	0.0	0.0	0.0	0.0
F1	80	20	0.0	0.0	0.0	0.0
F2	80	0.0	20	0.0	0.0	0.0
F3	79	0.0	20	0.0	0.0	1.0
F4	77	0.0	20	0.0	0.0	3.0
F5	75	0.0	20	0.0	0.0	5.0
L1	80	0.0	0.0	20	0.0	0.0
L2	80	0.0	0.0	0.0	20	0.0
L3	79	0.0	0.0	0.0	20	1.0
L4	77	0.0	0.0	0.0	20	3.0
L5	75	0.0	0.0	0.0	20	5.0

2.4 COMPOSITE CHARACTERIZATION

2.4.1 FOURIER TRANSFORM INFRARED SPECTROSCOPY

Fourier transform infrared spectroscopy (FTIR) was employed to monitor the changes in the DPTFs after PEG treatment. FTIR analysis was carried out using Tensor II machine (Bruker, Germany) with a wavenumber resolution of 4 cm^{-1}. The samples were mixed with KBr powder, pressed into pellets and analyzed in a range of 450 to 4000 cm^{-1} with an average of a 32 scans.

2.4.2 MECHANICAL PROPERTIES

To evaluate the mechanical properties of the composites, their impact strength and hardness were determined. Specimens for impact strength test were prepared using injection molding machine (Xplore 12ml, Netherlands). Charpy impact test was carried out using (CEAST Resil-Impactor tester) at room temperature with impact energy of 15 J. The specimens for impact test were prepared and notched according to ASTM (D256-10). A minimum of five specimens were tested and an average value was taken. Hardness was investigated by a Durometer in Shore D scale at room temperature according to ASTM (D2240) (Aminimum of 10 measurements were taken for each composite).

2.4.3 WATER ABSORPTION TEST

For water up take measurements, composites were pressed at 5 MPa using a small press at 180 °C to obtain thin (~ 1mm) films. Films with diameters of 2 cm were then cut and used. Before testing, all films have been dried at 80 °C in an air-circulated oven overnight, then placed in a desiccator. Subsequently, films were weighed with a OHAUS analytical digital balance (with a resolution of 0.1 mg). The films were immersed in water and weighed over time for three weeks at room temperature. The excess water on the surface of each film was removed with blotting paper before weighing. This test has been conducted in accordance with the procedure recommended by ASTM D570 [31]. Five specimens from each sample were weighed before and after immersion (over time) and the water absorption (WA) was calculated as follows:

$$WA\ (\%) = \frac{M_1 - M_0}{M_0}\ x\ 100$$

Where M_1 is the mass of the sample after immersion (g) and M_0 is the mass of the sample before immersion (g).

2.4.4 MORPHOLOGICAL PROPERTIES

The morphology of all composites and pure HDPE were studied. These morphological observations were carried out by means of a transmission electron microscope (SEM) at the Industrial Research Center, Tajura-Libya

3 RESULTS AND DISCUSSION

3.1 CHEMICAL STRUCTURE OF DPTFS BY FTIR

FTIR was used to identify the functional groups present in the DPTFs, thereby highlighting the chemical differences among the fiber constituents before and after PEG treatment. It has been reported that these fibers contain a variety of functional groups such as alkenes, phenolic hydroxyl group, aromatic groups, b-glucosi linkages and other oxygen-containing groups (ester, ketone and alcohol) [32]. In general, the characteristic bands of these functional groups correspond to the absorption bands of lignin, hemicellulose and cellulose [33]. Figure 1 presents the FTIR spectra of DPTFs obtained from the mesh before and after PEG treatment. Figure 2 shows the FTIR spectra for DPTFs obtained from the leaflets before and after PEG treatment. Generally, Figures 1 and 2 illustrate that DPTFs obtained from the mesh have different characteristic bands from those obtained from the leaflets. The broad bands at 3750-3200 cm^{-1} is typical of hydroxyl (-OH) groups (stretching and flexing vibration frequencies of the intra- and intermolecular hydrogen bonds of cellulose). This is probably due to the difference in the number of hydroxyl groups found in the different fibers [34]. The broadening of the hydroxyl group band could be also as a result of the presence of a mixture of intermolecular and intramolecular hydrogen bonds [35]. Sargunam et. al. [36] showed recently that the presence of hydrogen bonding is to cause a significant band broadening and to lower the mean absorption frequency in IR spectra.

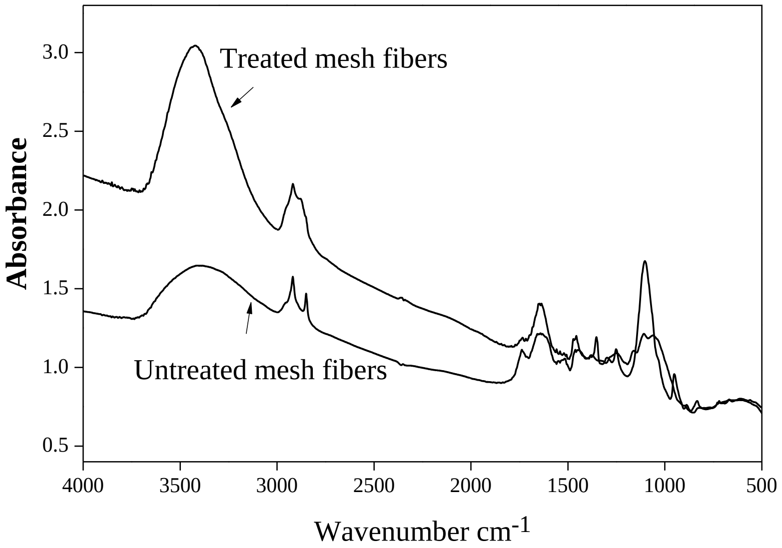

Figure 1: FTIR spectra of treated and untreated mesh fibers.

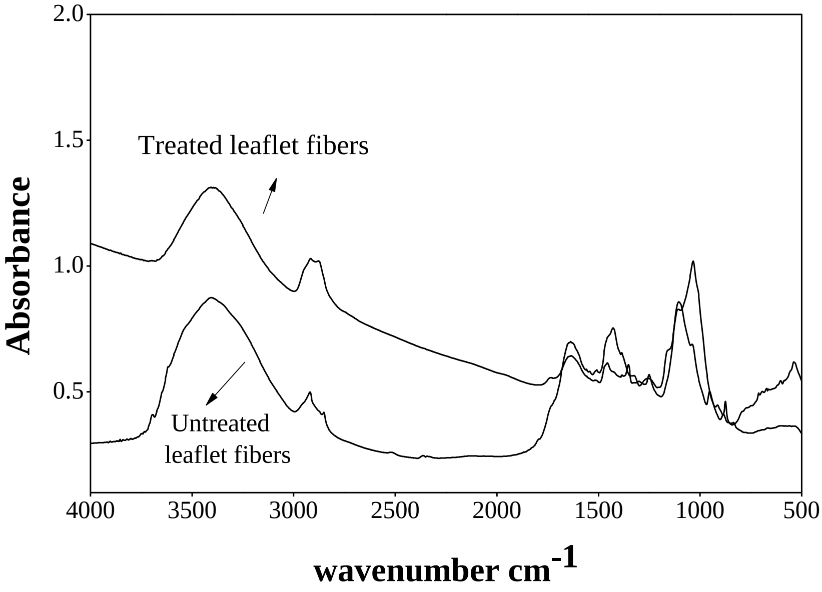

Figure 2: FTIR spectra of treated and untreated leaflet fibers.

From Figure 1, one can also see that the weak and broad absorption band for treated DPTFs obtained from the mesh at 3750-3200 cm^{-1} of -OH groups was intensified (became narrower and more defined) after PEG treatment, suggesting the occurrence of hydrogen bonding between PEG and the fibers. This could lead to reduce the number of -OH groups from the fiber surface, which results in fibers with higher hydrophobic nature [32]. The absorption band at 2990-2905 cm^{-1} are due to the stretching vibrations of CH_2. The small absorption band at 2890-2805 cm^{-1} are due to the C–H symmetric stretching of the methylene (CH_2 and CH_3) groups [37]. The latter two bands are generally overlapped after PEG treatment. This means that the proportions of CH_2 and CH_3 were higher in the treated fibers than in the untreated raw fibers. This is rather expected because PEG contains a greater proportion of these groups, which can be recorded in the FTIR spectra. Similar observations were made by Francisco et. al. [38].

A small band was observed at 1780-1714 cm^{-1} due to the carbonyl (C=O) stretching from the ester linkage of hemicellulose and lignin. An increase in the intensity of this band was observed after the treatment with PEG. This could indicate a slight change in hemicellulose and lignin has occurred due to the treatment with PEG. Furthermore, the peak representing the ether groups in treated fiber at 1253 cm^{-1} had changed noticeably; it became wider compared to the same peak in the untreated fiber spectrum. This may indicate the removal of some materials during PEG treatment [39]. Overall, it appears that treatment of the DPTFs obtained from the mesh with PEG resulted in a significant interaction between the PEG and the fiber via hydrogen bonding.

From Figure 2, it can be seen that, contrary to the DPTFs obtained from the mesh, no significant broadening of the absorption band for the treated DPTFs obtained from the leaflets at 3750-3200 cm^{-1} of -OH groups has occurred in comparison to the same band of the untreated leaflets. Furthermore, treatment of the DPTFs obtained from the leaflets fibers with PEG did not cause any other significant changes in the FTIR spectra. From Figure 1 and 2, one can clearly see that the influence of PEG treatment was much more distinct in the case of DPTFs obtained from the mesh than that of DPTFs obtained from the leaflets.

3.2 MECHANICAL PROPERTIES DETERMINATION

Generally, the properties of NFs reinforced polymer composites depend mainly upon various factors such as: fiber loading, fiber size, fiber orientation, stacking sequences, fiber surface treatments, degree of interfacial bonding, and incorporation of other additives and/or coupling agents [40]. To study their mechanical properties, the shore D hardness and impact strength of the prepared composites in this study were determined.

Our results showed that treating the fibers with low molecular weight PEG and using high molecular weight PEG as a coupling agent improved the impact strength of composites considerably compared to pure HDPE. The impact strength results of composites made with DPTFs obtained from the mesh and leaflets are shown in Figure 3 and 4. Figure 3 shows that composite made with DPTFs obtained from untreated mesh showed an improved value of 9.2 $KJ.m^{-2}$, which was higher than that of pure HDPE (8.1 $KJ.m^{-2}$). The addition of treated DPTFs resulted in composites with improved impact strength of 10.1 $KJ.m^{-2}$. Moreover, the addition of PEG6000 to the composite as the coupling agent enhanced the impact strength significantly compared to pure HDPE and composites made with only treated DPTFs. The highest impact strength of 15.1 $KJ.m^{-2}$ was obtained for composites containing 5 wt% PEG6000. This was attributed to better fiber-matrix adhesion as a result of the presence of PEG6000, therefore better fiber distribution occurred leading to better impact resistance (e.g., higher impact strength) [41-44]. Coupling agents improve the interfacial properties of fillers and polymers by reducing the interfacial tension which reduces the agglomeration tendency of filler particles [45]. Therefore, composites with better fiber distribution and mechanical properties can be obtained.

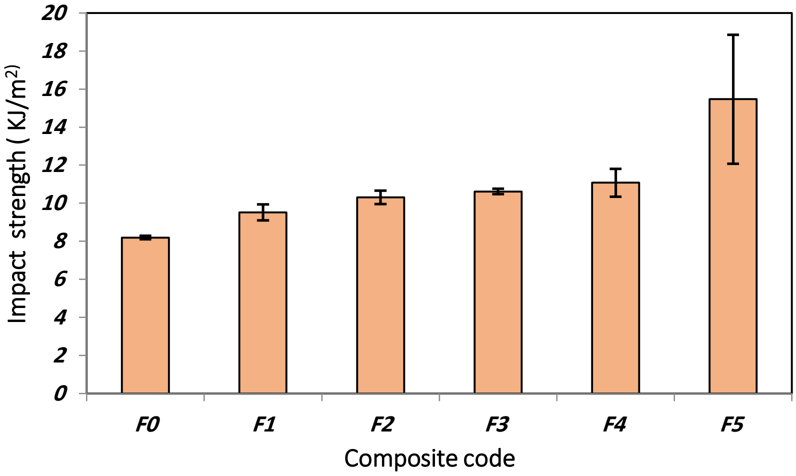

Figure 3: Impact strength for composites made with DPTFs obtained from the mesh.

Similar observations were obtained for composites made with DPTFs obtained from the leaflets. As can be shown in Figure 4, the highest impact strength value of 12.0 KJ.m^{-2} was observed when 3 wt% of PEG6000 was used. Contrary to the composite made with mesh fibers, the addition of more PEG6000 (5 wt%) did not improve the impact resistance of the composite. Once again, this was attributed to better fiber-matrix adhesion and therefore fiber distribution, which resulted in improved impact resistance of the final composite [15].

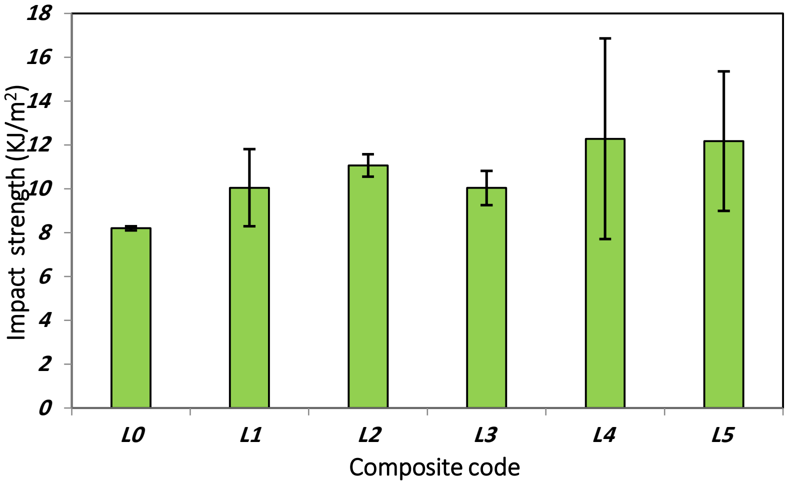

Figure 4: Impact strength for composites made with DPTFs obtained from the leaflets.

The surface hardness of the obtained composites was also investigated. The shore D hardness values of HDPE and all composites are shown in Table 2. As can be seen in Table 2, the use of PEG in general resulted in composites with higher shore D hardness. Composites with untreated DPTFs obtained from the mesh and leaflets showed similar to that of pure HDPE (~57). All composites made with treated fiber and/or PEG as the coupling agent had higher values (higher than that of pure HDPE and composites made with untreated fibers) and shore D hardness ranging from 58.7 to 63.8.

Table 2: Shore D hardness of pure HDPE and the prepared composites.

Composite code	Shore D hardness
F0/L0 (HDPE)	57.5
F1 (UMPE)	57.3
F2 (TMPE)	63.8
F3 (TMPE1)	61.6
F4 (TMPE3)	58.7
F5 (TMPE5)	60.0
L1 (ULPE)	57.4
L2 (TLPE)	59.3
L3 (TLPE1)	61.5
L4 (TLPE3)	62.1
L5 (TLPE5)	59.0

It has been shown that NFs can improve the fracture toughness, crack resistance, tension performance, flexural properties, impact strength, and fatigue behavior of composites [46]. Results showed that composites made with untreated fibers (both mesh and leaflets) resulted in the lowest value of the impact strength and shore D hardness in comparison to other composites that contain treated fiber and PEG as the coupling agent. This was attributed to better fiber distribution at the presence of PEG, which improved deformation and ductile mobility of polymer molecules increasing the capability of composites to absorb energy during crack propagation [47].

3.3 WATER ABSORPTION BEHAVIOR

It is well known that composites based on NFs are sensitive to water [48, 49]. Therefore, it is of a great interest to study the water absorption (WA) characteristics of such composites. Absorption of water could affect the polymer matrix structure and the fiber-matrix interface, therefore resulting in a big change of bulk properties such as dimensional stability as well as mechanical and physical properties [50]. In this study, WA was studied gravimetrically by immersing the composites in water at room temperature and recording the change of sample weight over a period of three weeks. Figure 5 and 6 show the WA levels for all composites prepared with DPTFs obtained from the mesh and leaflets, respectively.

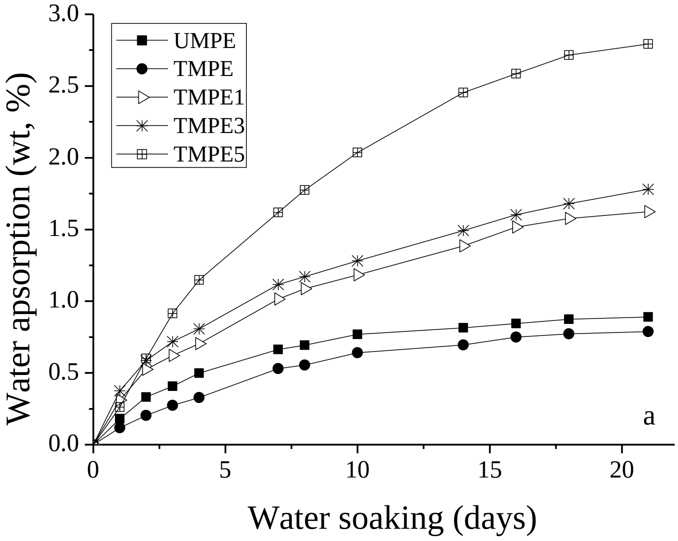

Figure 5: WA of HDPE/DPTF composites prepared with DPTFs obtained from the mesh.

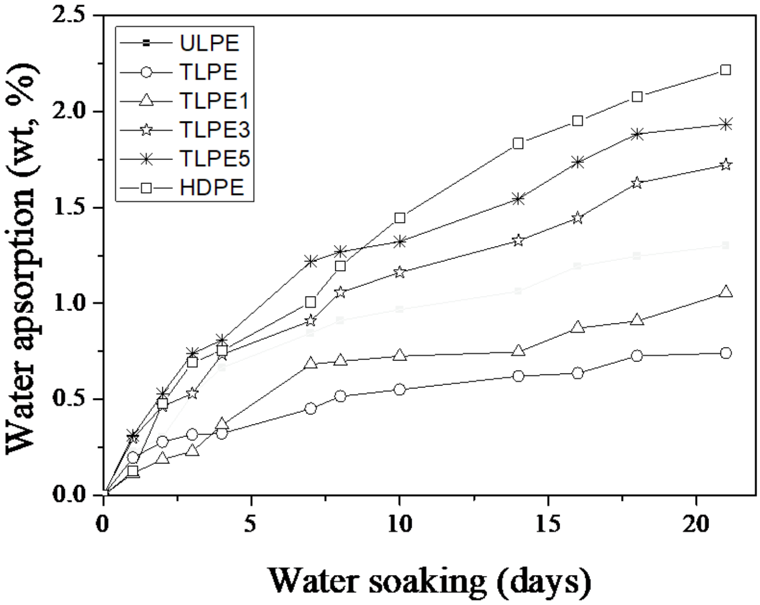

Figure 6: WA of HDPE/DPTF composites prepared with DPTFs obtained from the leaflets.

As can be seen in Figure 5 and 6, the incorporation of treated and untreated DPTF (mesh and leaflet fibers) had no significant effect on the water absorption of HDPE. Furthermore, the addition of PEG as a coupling agent resulted in no change in the WA behavior of composites. In general, all composites showed a very low water uptake. It is known that WA of such composites can be affected by the existence of lumens, holes, voids, flaws, poor interfacial adhesion, and microcracks at the interface between the DPTF and the polymer matrix [5].

3.4 MORPHOLOGICAL OBSERVATIONS OF THE COMPOSITES

SEM analysis was used to examine the morphological properties of the composites. The SEM was performed on composites made with DPTFs obtained from the mesh, which contain PEG as a treatment agent as well as a coupling agent. Figure 7 shows the SEM images of composites made with untreated DPTFs at different magnifications. The images in Figure 7 clearly show the formation of a rough surface with lots of voids and holes. Furthermore, the fibers appear to be separated, where fiber pullouts from the polymer matrix has occurred (see figure 7 b). However, composites made with the treated DPTFs had films with different much better surface roughness where no fiber aggregation is observed (see Figure 8). Moreover, no sign of voids, holes and/or fiber pullouts from the matrix were observed in these composites. This indicates that the level of interfacial interaction between the fiber and the HDPE polymer in the composite made with treated fibers is much better than that in composite with untreated fibers. This may also explain the higher shore D hardness and impact strength values obtained for composite with treated fibers in comparison to composite with untreated fibers (see Table 2 and Figures 3 and 4) . This is in a good agreement with the results of WA, where these composites showed very low level of water uptake (see Figure 5).

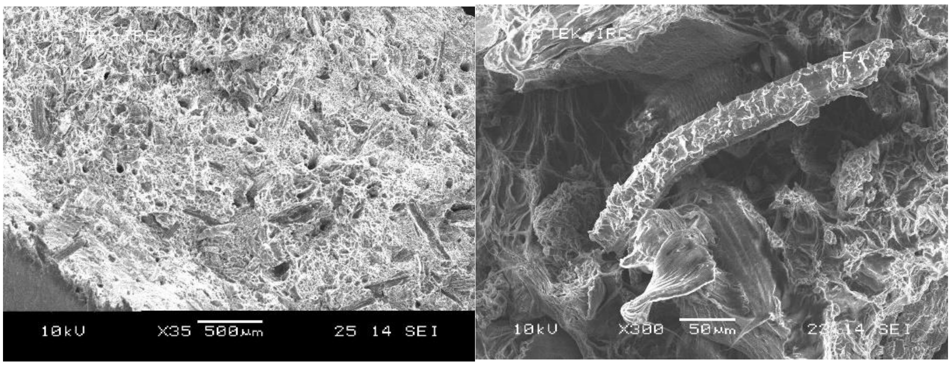

Figure 7: SEM images of composites made with untreated DPTFs obtained from the mesh: a) low magnification and b) at higher magnification.

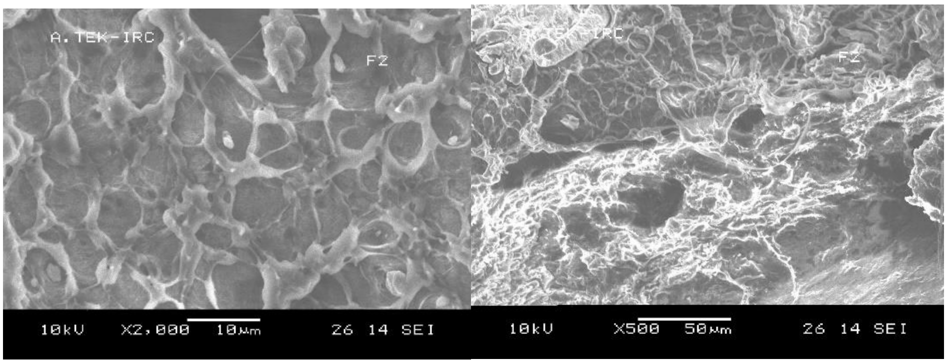

Figure 8: SEM images of composites made with treated DPTFs obtained from the mesh: a) low magnification and b) higher magnification.

As mentioned before, high molecular weight PEG was used as a coupling agent. Therefore, it was important to see the effect of PEG on the morphology of the obtained composites. Figure 9 illustrates the SEM images of composites containing 1 and 3 wt% PEG as the coupling agent. No formation of aggregation, fiber debonding and fiber pullout were observed, indicating the presence of a strong interfacial interaction between the fiber and the polymer matrix. The fibers appear to be finely distributed and completely covered with the polymer matrix. This may explain the higher impact strength values, which were obtained for these composites. The use of PEG as the coupling agent led to reduce the interfacial tension between the filer and the polymer, which resulted in better fiber distribution (i.e., the formation of composites with improved impact strength and shore D hardness).

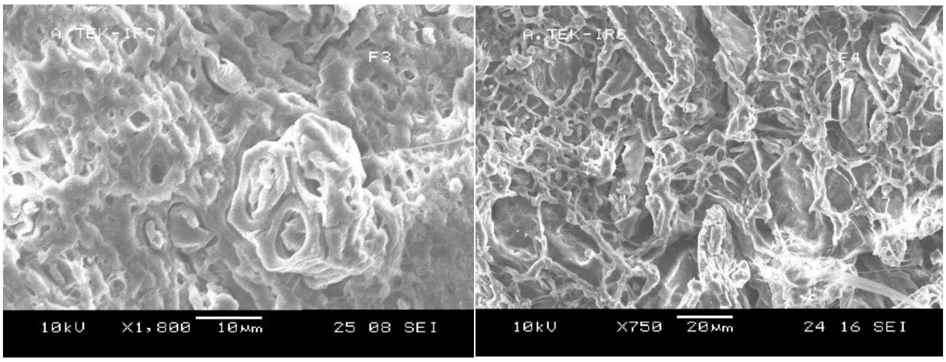

Figure 9: SEM images of composites containing a) 1 w% and b) 3 wt% PEG as the coupling agent.

4 CONCLUSIONS

The combination effect of using low and high molecular weight polyethylene glycol (PEG) as a treatment and/or coupling agent, respectively on mechanical properties and water absorption (WA) behavior of high density polyethylene/ date palm tree fibers (HDPE/DPTFs) composites was investigated. Two different parts of the date palm tree, namely mesh and leaflets were used to obtain the DPTFs. The following conclusions can be drawn:

- Composites made with treated DPTFs fibers only (mesh and leaflets) exhibited higher shore D hardness and impact strength value than those of pure HDPE and composites made with untreated DPTFs.
- The addition of high molecular weight PEG as the coupling agent resulted in even higher impact strength and shore D hardness. This was attributed to the occurrence of good fiber-matrix adhesion due to the presence of PEG as the coupling agent.
- Morphological observations revealed the formation of aggregation, fiber debonding and fiber pullout in composites made with untreated DPTFs, indicating weak interfacial interaction between the fiber and the HDPE matrix. However, adding the low and high molecular weight PEG resulted in composites with better fiber distribution, where no fiber aggregation or debonding are observed.
- The addition of PEG in general did not affect the WA behavior of the composites, which were similar to that of pure HDPE

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ايثيلين جلايكول كعامل معالج واقتران فى مركبات بوليمرية من بولي ايثيلين عالي الكثافة مع الياف من نخيل التمر

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الملخص

تم فى هذه البحث دراسة بعض الخصائص الميكانيكية وسلوك امتصاص الماء لمواد مركبة من البولي إيثيلين عالي الكثافة مع ألياف من نخيل التمر. حيث استخدمت اجزاء مختلفة من النخلة (الليف و السعف). كان التركيز على دراسة تأثير اضافة بولي إيثيلين جلايكول بوزن جزيئى صغير واخر كبير كمادة معالجة و كعامل اقتران (على التوالي) على الصلادة و مقاومة الصدم و سلوك امتصاص الماء للمواد المركبة الناتجة. كما تم فحص الخصائص المورفولوجية للمواد المركبة الناتجة. أظهرت النتائج أن معالجة اللياف النخيل بواسطة بولي ايثيلين جلايكول كان له تأثير كبير، مما أدى إلى الحصول على مواد مركبة ذات صلادة ومقاومة صدم أفضل من تلك التى يتمتع بها البوليمر النقي و كذلك المواد المركبة المصنوعة من ألياف غير معالجة. علاوة على ذلك ، أدى استخدام بولي ايثيلين جلايكول كعامل اقتران إلى تحسين اكبر فى الصلادة ومقاومة الصدم ، مما يشير إلى وجود تفاعل قوي بين الألياف وجزيئات البوليمر. كشفت كذلك الفحوصات المورفولوجية للمواد المركبة و المحضرة من الألياف غير المعالجة عن وجود بعض الألياف المتراكمة والمفصولة عن جزيئات البوليمر. على النقيض من ذلك ، لم تظهر المواد المركبة المحضرة باستخدام بولي ايثيلين جلايكول كمادة معالجة و/أو كعامل اقتران أي تراكم للألياف أو انفصال عن البوليمر مما سبب فى تحسين الخصائص. كما انه وبشكل عام ، لم يكن لاستخدام بولي ايثيلين جلايكول أي تأثير يذكر على سلوك امتصاص الماء للمواد المركبة، والذي كان مشابهًا لسلوك البوليمر النقي.

الكلمات الدالة:
الخصائص الميكانيكية.
بولي ايثيلين جلايكول.
بولي ايثيلين عالي الكثافة.
نخيل التمر.

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