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BIOCOMPOSITES USING TUNISIAN MARINE BIOMASS: POSIDONIA OCEANICA AS FILLER

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ABSTRACT

During this study, lignocellulosic fibres from marine biomass namely *Posidonia oceanica* was investigated as reinforcing elements for thermoplastic matrix-based composites. *P. oceanica* a dominant Mediterranean Sea grass was used as a filler to produce biocomposites. These natural fibres are sustainable low cost by-products and environmentally friendly raw materials. Several biocomposites films were prepared from *P. oceanica* and BC-LBI01 matrix, using a Brabender mixing device at different fibre loadings from 0 wt. % to 50 wt. % (w/w with respect to the matrix). The ensuing films were characterized by their morphological using scanning electron microscopy (SEM). Besides, their thermal and mechanical properties were established by differential scanning calorimetry (DSC) and dynamic mechanical analysis. The obtained results show that *P. oceanica* enhanced the properties of the initial matrix and that these natural elements can be considered as promising fillers for preparing biocomposites materials.

KEYWORDS

Posidonia oceanica; biocomposite materials; SEM; mechanical and thermal properties.

1. INTRODUCTION

Over the last decade, the utilization of lignocellulosic material for the processing of novel biocomposites has attracted (Mohanty et al., 2005; Habibi et al., 2008; Khiari et al., 2011a, 2011b, 2011c) growing interest because these natural fibres are known (i) sustainable, (ii) their biorenewable character, (ii) their ubiquitous availability in a variety of forms, (iii) low cost by-products and (iv) environmentally friendly raw materials (Belgacem, Gandini, 2008). Indeed enormous interest in the development of new composite materials filled with natural fibres has been shown by important industries such as the automotive, construction (Coutts et al., 1994; Pothan, 2009; Savastano et al., 1999; Thomas, Zhu et al., 1994) and or packaging industry (Antunes et al., 2000; Belgacem et al., 1986; Cordeiro et al., 2004; Khiari et al., 2010), have focused their attention to the development of new materials filled with natural fibres or powders. Thus, to satisfy the large demand of natural fibres, it becomes a really challenging to supply the needs of all the users at reasonable costs, with required quantities and qualities. In fact, the lignocellulosic fibres are already extensively used for many applications. They are used in textile industries (to manufacture clothing and furniture), papermaking and packaging industries, (Mansouri et al., 2012; Mechi et al., 2016; Youssef et al., 2012, 2013) in pharmaceutical areas (compresses, dressings, bandages, excipient, drugs etc.,) and the preparation of innovative materials such as bio-composites (Bettaieb et al., 2015; Khiari et al., 2011a,

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2011b, 2011c). Consequently, the consumption of lignocellulosic fibres is increasing, and it is becoming increasingly difficult to satisfy the large request. This is the reason why, non-wood species and the annual plants can be considered as suitable alternative sources of lignocellulosic fibers, especially in forest-poor regions.

Posidonia oceanica is the dominant sea grass in the Mediterranean Sea. P. oceanica play an important role in the processes concerning beach and dunes systems in Mediterranean countries. It is (i) a major element preserving the Mediterranean ecosystems, (ii) protecting from coastal erosion, (iii) and regulating CO₂ absorption in the sea and in the atmosphere. Whereas, large quantities of P. oceanica fragments accumulated on Mediterranean coasts, which impose the cleaning of the beaches every summer. Dural et al. (2011) estimated that the total primary *P. oceanica* production is in the range of 5×10^6 -- 5×10^7 ton per year. The valorization of this available and renewable lignocellulosic biomass can be considered as a suitable solution for this problem. The first valorization of this biomass was investigated to the extraction of phenolic acid (Pergent et al., 1995) from the leaves as well as to use as nutriment for the animals. Recently, thus Mediterranean Sea is a good source of cheap waste material for fibre production (Aguir, Mhenni, 2006, 2009; Gezguez et al., 2009; Khiari et al., 2010, 2011a, 2011b, 2011c; Khiari, 2010). Moreover, it has been studied as a low cost and renewable adsorbent for removing dyes or phenol (Ncibi et al., 2006a, 2006b, 2008; Gezguez et al., 2009) or as a source of cellulose (Aguir, Mhenni, 2006; Gezguez et al., 2009; Khiari et al., 2010, 2011a, 2011b, 2011c). Furthermore, these marine biomass by-products were found suitable for the valorization of such crops as cellulose fibres (Khiari et al., 2010, Bettaieb et al., 2015a, 2015b, 2015c, 2015d), for papermaking applications (Khiari et al., 2010), but could also be used for cellulose derivatives (Aguir, Mhenni, 2006, 2009; Gezguez et al., 2009; Khiari et al., 2010, 2011c) and/or for fibre-reinforced composite materials (Khiari et al., 2010, 2011a, 2011b).

The main objectives of this paper are studied the potential to use marine biomass P. oceanica as reinforcing elements. Different composite films were firstly prepared from Posidonia and BC-LBI01 (as matrix), using a Brabender mixing device. Then, the obtained films were carefully characterized by several techniques such as by scanning electron microscopy (SEM) and tensile tests. This work open a really window to valorise various agricultural or industrial by-products available locally in our case the present idea fits within this same strategy and intends to confer an updated value to a marine residue (P. oceanica balls) largely available in Tunisia.

2. MATERIALS AND METHODS

2.1. Posidonia oceanica

The P. oceanica balls (Figure 1.a) were used as new filler to reinforce biocomposite materials. The lignocellulosic materials were collected from Monastir (August 2015). This marine biomass were washed, rinsed with distilled water, in order to eliminate sand and then dried under natural condition during the month of September 2015. The obtained materials were milled and sieved to a granulometry having a size of 50 µm. The particle size distribution of *P. oceanica* is presented in Figure 1b, which shows that a large distribution profile is obtained. Even if the distribution is centred to 50 µm, particles with much smaller

 $(1 \,\mu\text{m})$ or bigger (400 μm) sizes are present.





Figure 1: (a) P. oceanica balls and (b) particles size distribution of P. oceanica.

2.2. Matrix

During this study, BC-LBI01 is a thermoplastic matrix which was used. It is an agromaterial descending from the BioCérès range. It was compound from a wheat flour-based product. BC-LBI01 is 100% biodegradable and from renewable resources which is particularly appropriate for the manufacture of plastic films (10 to 200 microns). (<u>https://plastics.ulprospector.com/fr/datasheet/e127736/bioceres-bc-lbi01</u>).

2.3. Composite preparation

The same procedure established by Khiari et al. (2011a) was kept up with in order to preparing the biocomposite films. Briefly, lignocellulosic fragments from *P. oceanica* reinforced BC-LBI01 biocomposites were established by mixing the thermoplastic matrix with different fibres loadings (10, 20, 30, 40 and 50% w/w) using a Brabender mixing device. This apparatus equipped with a rotor speed of 50 rpm and a mixing chamber temperature of 160°C, the mixture was kept during 10. After incorporation steps, the resulting materials were moulded by hot pressing in a hydraulic press (at 150 °C, under 10 ton and for 5 min) with a suitable steel mould into rectangular films ($10 \times 5 \text{ cm}^2$) of about 0.5 mm thickness. Finally, the mould was left to cool down, and the biocomposites films were recovered when the temperature was about 35 °C. All the biocomposites films were prepared in triplicate.

2.4. Characterization of prepared films

2.4.1. Scanning electron microscopy (SEM)

The morphology of the different films (composites) was observed using the scanning electron microscopy (SEM). In fact, each prepared sample was first of all frozen under liquid nitrogen during 5 to 10 min then fractured. Finally, the fractured surface was metallized with a gold/Palladium coating layer, before analysis.

2.4.2. Differential Scanning calorimetry

The thermal properties of ensuing sample (biocomposites films) were investigated using the differential scanning calorimetry (DSC) experiments. This analysis was performed thanks to a DSC Q100 from TA instrument. The test consists round 10 mg of the sample were placed in a DSC cell, for each prepared composites. Each sample was heated from -90 to 250°C under a heating rate of 10 °C min⁻¹. The test was carried at least in duplicate.

2.4.3. Tensile Testing

The mechanical behaviour of all the prepared composites was investigated using RSA 2 spectrometer from Rheometricts working in tensile mode. The elongation and stress at break, as well as, the Young's Modulus were determined. The sample dimension was $30 \times 5 \times 0.4$ mm³. These measurements were replicated 5 times and the difference between the various values obtained was within an experimental error of 5 %.

2.4.4. Dynamic mechanical analysis

The mechanical behaviour of the composite films, cut into probe samples with dimensions of $30 \times 5 \times 0.4 \text{ mm}^3$, was tested using a RSA 3 DMA apparatus from Rheometrics, working in the tensile mode. The dynamic mechanical analysis (DMA) measurements of the biocomposite films were carried out under isochronal conditions at 1 Hz, and the temperature scanning interval varied from -100 to 250 °C, with a heating rate of 2 °C min⁻¹. The samples were previously conditioned for 24 h under controlled temperature (23 °C) and relative humidity (50%), before being tested. These measurements were also carried out at least in duplicate.

3. RESULTS AND DISCUSSIONS

The chemical composition (Table 1) of the *Posidonia oceanica* balls (Khiari et al., 2010), have showed that this raw material contains considerable amount of cellulose, which justifies considering its valorisation in cellulose derivatives field and/or as a source of fibres for papermaking applications or for cellulose fibres-reinforced composite materials.

Different composite materials were prepared using *P. oceanica* as new filler and BC-LBI01 as thermoplastic matrix. The *P. oceanica* particles were introduced into the matrix up to a maximum loading of 50 wt.%,

without any significant change in the aspect of the ensuing films. In fact, the particles agglomeration was apparently avoided.

	Content (%)	Standard
Cold water solubility	7.3	T207 cm-08
Hot water solubility	12.2	T207 cm-08
Ethanol - toluene solubility	10.7	T204 cm-07
1% sodium hydroxide solubility	16.5	T212 om-07
Ash	12	T211 om-07
Klason lignin	29.8	T222 om-06
Holocellulose	61.8	Wise et al., 1946
α-cellulose	40	T203 cm-99

Table 1. Chemical composition of *P. oceanica* (Khiari et al., 2010).

3.1. Morphology

Figure 2 illustrate the observation of the fractured surface film composites prepared by thermoplastic matrix "BC-LBI01" using SEM instrument. It can be deduced that the prepared composites with different fibre loadings present a highly homogeneous structure. Thus, in all cases, the structure of the composite is as homogeneous as that of the matrix (Figures 2).





Figure 2: SEM micrographs of the fractured cross-sections of the composite films.

This rather good information indicates that the surface of the marine biomass filler is clean enough to yield a good interfacial adhesion with the matrix. In fact, the absences of holes as well as the intimate fibre/matrix interface are relevant data predicting rather good mechanical properties of the resulting composites. Moreover, from the SEMs micrographs, it can be deduced that the experimental condition for the composites preparation and those used to prepare the samples for SEM analyses seems to be optimal, since no failures were observed and deducted. Consequently a good dispersion and strong interfacial adhesion were clearly observed. These features of homogeneity can also be justified by the absence of holes or cracks inside the prepared films. The idea here is the use of the lignocellulosic fibers without any treatment, because we are dealing with the valorization of a waste. Moreover, any additional purification steps will induce extra costs and will make meaningless the full approach. Nevertheless, it is worth to mention that the grinding treatments can not break the non-cellulosic material from cellulose species such as hemicelluloses and lignins induce though the surface specific of obtained particles it can be increased and consequently increases a physical adhesion can be observed between matrix and the filler.

3.2. Thermal properties

The thermal properties of the matrix as well as those of all the other biocomposite films prepared in this work were studied and the results are summarized in figure 3. The DSC of the matrix presents three phenomena namely: (i) the glass transition temperature (Tg) which it was detected at 48.34°C and 130°C, (ii) the crystallization temperature which was observed at ~75°C and finally (iii) the melting temperature which was shown at 146.35°C. Except for the biocomposite at 10wt% of loading fibers, the DSC tracings of the prepared films are large different to that of the matrix. In fact, in all the cases, a glass transition temperature (Tg) very close to that of the matrix (about to 48 and 130 °C) was detected, suggesting that the introduction of the lignocellulosic fillers did not affected the Tg of the matrix. This feature is quite interesting and very useful in practice because the produced films keep their flexibility even for the highest filler loading investigated here. Moreover, the melting temperature (Tf) seems also kept constant and the incorporation of lignocellulosic fragment did not affect the Tf value. Regarding, the crystallization temperature, it can be noticed probably that the presence of lignocellulosic fibers partially prevents chains BC-LBI01 crystallize during the subsequent cooling in the implementation of the material. The crystal

amorphous state. It is likely that the reduction of the material crystallinity resulting in the reduction of the order of 10 ° C observed for the glass transition temperature of the composite (see Figure 3). A decrease in the glass transition temperature usually corresponds to a greater mobility of the amorphous areas. A portion of the frozen matrix of amorphous chains in the glassy state crystallizes upon heating beyond Tg as shown in the exothermic peak observed for the composite.



Figure 3: SEM micrographs of the fractured cross-sections of the composite films.

3.3. Mechanical properties

The evolution of the mechanical properties in terms Young's Modulus, strength and elongation at break as function of different fibre loadings of 0%, 10%, 20%, 30%, 40% and 50% is show in Table 2. The tensile properties were investigated at room temperature (25 °C). From this Table, one can draw different concluding remarks:

- The Young's Modulus of the prepared film increased with adding of obtained fibres from *Posidonia*. For an example the obtained Young Modulus of composite material filled with (50 %wt) is 3 time greater then that of the unfilled composites film. As excepted, this behaviour can be explained by the incorporation of filler which enhanced the reinforcement materials (Abdelmouleh et al., 2007; Alhuthali et al., 2012; Bledzki, Gassan, 1999; Dhakal et al., 2007; Faruk et al., 2012 ; Hristove, Vasileva, 2003; Khiari et al., 2011a, 2011b; Mansouri et al., 2014; Mohanty et al., 2001; Oksman, Clemons, 1998; Wise et al., 1946). In fact, as previously discus by Faruk et al. (2012) and Marzouk et al. (2015) that increasing fiber content in the composites increases the composite's stiffness significantly. Additionally its strength is increased through the addition of natural fibers. Higher fiber content improves the impact strength and unfortunately increases the water uptake. Moreover, the composite's ductility can be affected. The fiber length and its geometry also play a decisive role in composites. Usually, most mechanical properties of a fiber can be enhanced by increasing the aspect ratio.
- The incorporation of our marine biomass filler to the thermoplastic matrix have slightly affected into the stress at break. The stress break varies from 5.7 to 9.7 MPa. Regarding now, as expected that the elongation at break of the obtained films decrease upon fibre addition. This can be explained by the effects of lignocellulosic which reduce the deformation capability.

Wt.%	Elongation at break (%)	Stress at break (MPa)	Young's Modulus (MPa)
0	130.1	5.7	97.7
10	70.3	6.4	154.9
20	26.9	6.5	163.8
30	11.3	6.5	204.4
40	7.3	9.7	208.3
50	4.6	8.8	214.4

Table 2. Mechanical properties of prepared films with different fibre loadings (wt%).

Figure 4 presents the dynamic mechanical measurements for BC-LBI01 biocomposite materials filled with different fibre contents (0, 10, 20, 30, 40 and 50% w/w). The evolution of the storage tensile modulus, log (*E*'), and that of the loss factor (tan δ) *versus* temperature in isochronal conditions at a frequency of 1 Hz is presented.



Figure 4: Evolution of (a) the logarithm of the storage tensile modulus (E') and (b) the loss angle tangent tan (δ) vs temperature at 1 Hz for BC-LBI01-based biocomposites.

The obtained results from the DMA show the evolution of the storage modulus versus temperature for the tested bicomposites materials. The behavior of these materials is identical in terms of glassy and rubbery

modulus regardless of composition. The fall observed module to 70°C which is attributed to the main phenomena of relaxation associated with the glass transition phenomenon in accordance with the DSC measurements. The module increase observed after the main relaxation probably corresponds to the crystallization of the matrix because it manifests itself in the temperature range of the exothermic peak observed by DSC. It is strange that even the uncharged matrix, this module increase is observed when crystallisation was absent from the DSC thermogram. Nevertheless, this increase module is shifted to higher temperatures compared to composites. The flow of material is done to 160°C which also in accordance with the melting points given in the DSC measurements.

Figure 4.b presents tan (δ) vs. temperature and shows the presence of one relaxation processes situated at around 40°C. These transitions are associated with the chain segment mobility of the polymer branches and to molecular motion within the crystalline phase, respectively. As expected, this result was observed by many research studies (Abdelmouleh et al., 2007; Alhuthali et al., 2012; Bledzki, Gassan, 1999; Dhakal et al., 2007; Faruk et al., 2012 ; Hristove, Vasileva, 2003; Khiari et al., 2011a, 2011b; Marzouk et al., 2015; Mansouri et al., 2014; Mohanty et al., 2001; Oksman, Clemons, 1998; Wise et al., 1946).

% Raw material/ % BC-LBI01	E'C25 (MPa)	Tf (°C)	E'C25 normaliser (MPa)
0	162	125.4	162
10	185	126.9	174
20	205	132.5	177
30	274	126.5	180
40	308	129.8	191
50	318	127.7	186

Table 3. Dynamic mechanical properties of the prepared films with different fibre loadings (wt %).

Table 3 summarised the mechanical properties of the prepared films with different fibre loadings (wt %). From Table 3 and Figure 4.a, one can draw the following concluding remarks: (i) For temperatures below the glass transition temperature, BC-LBI01 is in its glassy state and its storage modulus slightly decreases with temperature but remains roughly constant at around 1 GPa. (ii) With the addition of *P. oceanica* particles, the modulus of all the prepared composites increases by a factor of 3, compared with unfilled composites. Thus, the modulus of the unfilled matrix at 25°C is 160 MPa whereas that of the composite filled with 50% w/w of *P. oceanica* reaches 318 MPa. As expected, this behaviour can be explained by the incorporation of filler which enhances the reinforcement.27-35-38(wiem) (iii) Below the Tg, the *Posidonia* particles prolonged slightly the rubbery plateau of prepared composites, as confirmed by the increase of the melting temperature (Tf). Thus, for example, the melting temperature of the composite material filled with 50% w/w of *Posidonia* is i.e. 127°C whereas the unfilled matrix is i.e. 125°C. (iv) It can be deduced that incorporation of ligncellulosic marine can be kept the performance of material at temperature around 50°C. These results were also observed in the DSC tracing.

4. CONCLUSION

BC-LBI01 matrix based biocomposites reinforced with cellulosic fibers obtained from *P. oceanica* were prepared by an extrusion method to investigate the effect of fiber loading on green composite properties. Morphological and thermal analysis of the biocomposite films with SEM and DSC indicated the appropriate dispersion of the lignocellulosic fibers within the matrix at 10 wt. % until 50 wt.% loadings and subsequent improvement in mechanical properties. It is so important to signal that the The *P. oceanica* particles were introduced into the matrix up to a maximum loading of 50 wt.%, without any significant change in the aspect of the ensuing films. In fact, the particles agglomeration was apparently avoided. The obtained data show that these biocomposites with good thermal (degree of cristallinity, melting and glass transition temperatures) and mechanical properties (Young Modulus) can be prepared. This work clearly demonstrates that *P. oceanica* can be considered as a possible alternative source of material for composite applications.

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REFERENCES

Abdelmouleh, A., Boufi, S., Belgacem, M.N., Dufresne, A. (2007). Short natural fiber reinforced polyethylene and natural rubber composites: effect of silane coupling agents and fibers loading. *Composites Science and Technology*, Vol.67, 1627-1639.

Aguir, C., Mhenni, M.F. (2009). Preparation and characterization of new succinic anhydride grafted *Posidonia* for the removal of organic and inorganic pollutants. *Journal of Hazardous Materials*, Vol.172,N°2-3, 1579-1590.

Aguir, C., Mhenni, M.F. (2006). Experimental study on carboxymethylation of cellulose extracted from *Posidonia oceanica. Journal of Applied Polymer Science*, Vol.98, 1808-1816.

Alhuthali, A., Low, I.M., Dong, C. (2012). Characterization of the water absorption mechanical and thermal properties of recycled cellulose fibre reinforced vinyl-ester eco-nanocomposites. *Composites Part B: Engineering*, Vol.43, 2772-2781.

Antunes, A., Amaral, E., Belgacem, M.N. (2000). Cynara cardunculus L.: chemical composition and soda– anthraquinone cooking. *Industrial Crops and Products*, 12, 85–91.

Belgacem, M.N., Candini, A. (2008). *Monomers, Polymers and Composites from Renewable Resources,* Elsevier, ISBN: 978-0-08-045316-3.

Belgacem, M.N, Zid, M., Nicolski, S.N., Obolenskaya. A.V. (1986). Study of the chemical composition of alpha from Tunisia. *Chim Technol Drev Mej Sbor Trud*, Vol.8, 111-114.

Bettaieb, F., Khiari, R., Dufresne, A., Mhenni, M.F., Belgacem, M.N. (2015a). Mechanical and thermal properties of *Posidonia oceanica* cellulose nanocrystal reinforced styrene butadiene rubber. *Carbohydrate Polymers*, Vol.123, 99-104.

Bettaieb, F., Khiari, R., Dufresne, A., Mhenni, M.F., Putaux, J.L., Boufi, S. (2015b). Nanofibrillar cellulose from *Posidonia oceanica*: Properties and morphological features. *Industrial Crops and Products*, Vol.72, 97-106.

Bettaieb, F., Khiari, R., Hassan, M., Dufresne, A., Mhenni, M.F., Bras, J., Belgacem, M.N. (2015c). Preparation and characterization of new cellulose nanocrystals from marine biomass *Posidonia oceanica*. *Industrial Crops and Products*, Vol.72, 175-182.

Bettaieb, F., Nechyporchuk, O., Khiari, R., Mhenni, M.F., Dufresne, A. Belgacem, M.N. (2015d). Effect of the oxidation treatment on the production of cellulose nanofiber suspensions from *Posidonia oceanica*: The rheological aspect. *Carbohydrate Polymers*, Vol.134, 644–672.

Bledzki, A.K., Gassan, J. (1999). Composites reinforced with cellulose based fiber. *Progress in Polymer Science*, Vol.24, 221-274.

Cordeiro, N., Belgacem, M.N., Torres, I.C., Mourad. J.C.V.P. (2004). Chemical composition and pulping of banana pseudo-stems. *Industrial Crops and Products*, Vol.19, 147-154.

Coutts, R.S.P., Ni, Y., Tobias, B.C. (1994). Air-cured bamboo pulp reinforced cement. *Journal of Materials Science Letters*, Vol.13, 283-285.

Dhakal, H.N., Zhang, Z.Y., Richardson, M.O.W. (2007). Effect of water absorption on the mechanical properties of hemp fibre reinforced unsaturated polyester composites. *Composites Science and Technology*, Vol.67, 1674-1683.

Dural, M.U., Cavas, L., Papageorgiou, S.K., Katsaros, F.K. (2011). Methylene blue absorption on activated carbon prepared from *Posidonia oceanica* (L.) dead leaves: Kinetics and equilibrium studies. *Chemical Engineering Journal*, Vol.168, 77–85.

Faruk, O., Bledzki, A.K., Fink, H.P., Sain, M. (2012). Biocomposites reinforced with natural fibers. *Progress in Polymer Science*, 37, 1552-1596.

Gezguez, I., Dridi-Dhaouadi, S., Mhenni, F. (2009). Sorption of Yellow 59 on *Posidonia oceanica*, a non-conventional biosorbent: Comparison with activated carbons. *Industrial Crops and Products*, Vol.29, N°1., 197–204.

Habibi, Y., El-Zawawy, W.K., Ibrahim, M.M., Dufresne, A. (2008). Processing and characterization of reinforced polyethylene composites made with lignocellulosic fibers from Egyptian agro-industrial residues. *Composites Science and Technology*, Vol.68, 1877-1885. 10.1016/j.compscitech.2008.01.008.

Hristove, V., Vasileva, S. (2003). Dynamic Mechanical and Thermal Properties of Modified Polypropylene Wood Fiber Composites. *Macromolecular Materials and Engineering*, Vol.10, 798-806.

Khiari, R., Mhenni, M.F., Belgacem, M.N., Mauret. E. (2010). Chemical composition and pulping of date palm rachis and *Posidonia oceanica* – a comparison with other wood and non-wood fibre sources. *Bioresource Technology*, Vol.101, 775-780.

Khiari, R. (2010). Valorisation des déchets d'origine agricole et marine: Application dans les domaines textiles, papetiers et des composites, Thèse, Institut Polytechnique de Grenoble, France.

Khiari, R., Belgacem, M.N., Mhenni, M.F., Mauret. (2011a). New lignocellulosic material: *Posidonia oceanica* for composite materials. *Composites Science and Technology*, Vol.71, N°16., 1867-1872.

Khiari, R., Ferchichi, I., Mhenni M. F. (2010a). Study of liquids absorption and retention capacities of cellulosic materials and sodium cellulose carboxylmethylate prepared from *Posidonia oceanica*. *Fibers and polymers*, Vol.4, 593–597.

Khiari, R., Krouit, M., Belgacem, M.N., Mauret, E., Mhenni, M.F. (2011b). Preparation and characterization of a material based composite *Posidonia oceanica*. *Materiaux & Techniques*, Vol.100, 369-375.

Khiari, R., Mhenni, M. F., Belgacem, M.N., Mauret, E. (2011c). Valorisation of vegetal wastes as a source of cellulose and cellulose derivatives. *Journal of Polymers and the Environment*, Vol.19, 80-89.

Mansouri, S., Khiari, R., Bendouissa, N., Saadallah, S., Mhenni, F., Mauret, E. (2012). Chemical composition and pulp characterization of Tunisian vine stems. *Industrial Crops and Products*, Vol.36, 22-27.

Mansouri, S., Khiari, R., Bettaieb, F., Abou-Zeid, R.E., Malek, F., Mhenni, M.F. (2014). Characterization of composite materials based on LDPE loaded with agricultural Tunisian waste. *Polymer Composites*, Vol.36, 817-824.

Marzouk, W., Bettaieb, F., Khiari, R., Majdoub, H. (2015). Composite materials based on low-density polyethylene loaded with date pits Mechanical and thermal characterizations, *Journal of Thermoplastic Composite Materials*, doi: 0892705715618742.

Mechi, N. Khiari R, Ealoui, L., Belgacem, M.N. (2016). Preparation of paper sheet from cellulosic fibres obtained from *Prunus amygdalus* and *Tamarisk sp. Cellulose Technology and Chemistry*. In press.

Mohanty, A.K., Misra, M., Drzal L.T. (2005). *Natural fibers biopolymers and biocomposites*, CRC Press, ISBN 9780849317415.

Mohanty, A.K., Misra, M., Drzal, L.T. (2001). Surface Modification of Natural Fibers and Performance of the Resulting Biocomposites. *Composites interfaces*, Vol.5, 313-343.

Ncibi, M.C, Mahjoub, B., Seffen, M. (2006). Biosorption of phenol onto *Posidonia oceanica* seagrass in batch systems: Equilibrium and kinetic modelling. *Canadian Journal of Chemical Engineering*, Vol.84, N°4., 495-500.

Ncibi, M.C, Mahjoub, B., Seffen, M., (2008a). Investigation of the sorption mechanisms of metalcomplexed dye onto *Posidonia oceanica* (L.) fibres through kinetic modeling analysis. *Bioresource Technology*, Vol.99, N°13., 5582-5589. Ncibi, M.C., Altenor, S., Seffen, M., Brouers, F., Gaspard, S. (2008b). Modelling single compound adsorption onto porous and non-porous sorbents using deformed Weibull exponential isotherm. *Chemical Engineering Journal*, Vol.145, N°2., 196–292.

Oksman, K., Clemons, C. (1998). Mechanical Properties and Morphology of Impact Modified Polypropylene-wood Flour Composites. *Journal of Applied Polymer Science*, Vol.9, 1503-1513.

Pergent, G., Pergent-Martini, C., Boudouresque, C.F., (1995). Utilisation de l'herbier à *Posidonia oceanica* comme indicateur biologique de la qualité du milieu littoral en Méditerranée: *L'état des Connaissances*, Vol.54, 3-29.

Savastano H. Jr., Agopyan, V., Nolasco, A.M., Pimentel. L. (1999). Plant fibre reinforced cement components for roofing. *Construction and Building Materials*, Vol.13, 433–438.

Thomas, S., Pothan. L. (2009). *Cellulose fibre reinforced polymer composites*, Old City Publishing, Philadelphia, ISBN 9780849317415.

Wise, LE., **Murphy, M., D'Addieco, AA.** (1946). Chlorite holocellulose its fractionation and bearing on summative wood analysis and on studies on the hemicelluloses. *Paper Trade Journal*, Vol.122, 35-43.

Youssef, A.M., Ali El- Samahy, M., Abdel Rehim, M.H. (2012). Preparation of conductive paper composites based on natural cellulosic fibers for packaging applications. *Carbohydrate Polymers*, Vol.89, 1027-1032.

Youssef, A.M., Kamel, S., El-Samahy, M.A. (2013). Morphological and antibacterial properties of modified paper by PS nanocomposites for packaging applications. *Carbohydrate Polymers*, Vol.98, 1166-1172.

Zhu, W.H., Tobias, B.C., Coutts, R.S.P., Langfors, G. (1994). Air-cured banana-fibre-reinforced cement composites. *Cement and Concrete Composites*, Vol.16, N°1., 3-8.