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Characterization of Date Palm Wood Used as Composites Reinforcement

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This work reports the results of an experimental investigation on physical and mechanical properties of Algerian date palm tree residues in order to optimize their performances when used as reinforcement. The results have shown that all the samples are characterized by porous and fibrous structure with irregular surface, which contains a large number of uncompleted grown fibers (expected to be residual lignin). Concerning the mechanical properties of date palm fibers (DPF), the results show that they are comparable to those reported for coir and are lower than those reported for other natural fibers. However with regard to the specific mechanical properties, date palm fibers show higher values than those of other natural fibers. This is due to the low values of bulk density of date palm wood, especially of that of Petiole.

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1. Introduction

In view of finding alternative reinforcements, that are environmentally friendly and can provide the same performances as synthetic counterparts, researchers' interest has focused on the use of natural fibers as reinforcement in different matrices, because of their low density, low cost, renewability, and biodegradability. Various researches on potential utilization of natural fibers like coir, hemp, sisal, pineapple fibers, jute, etc., showed that the presence of these fibers in different composites is beneficial [1–4]. Date palm tree residues are one of the most important natural fibers in the world. They are obtained by seasonal pruning of palm trees which is an essentially agricultural practice. Algeria has more than 18 million date palms [5]. It produces approximately 630 000 tons of date palm residues per year. Worldwide, there are approximately 105 million palm trees, an estimated number of over 3 675 000 tons of residues are produced annually. Therefore from the economic and environmental point of view, the utilization of fibers from the date palm wood is a promising project. The use of this kind of fibers as reinforcement for composites was the subject of many investigations [3, 6–8]. This study has investigated the physical and the mechanical properties of date palm wood and its potential usage as a composite material. Knowledge of these properties is required in order to optimize the industrial process and materials.

2. Experimental part

2.1. Sample preparation

The natural fibers used in this study were pruning residues of date palm trees from Biskra Oasis in Algeria. Four types of date palm wood (Petiole PF, Rachis RF, Bunch BF and Fibrillium FF) were investigated. The chosen samples were cleaned with water to remove dust and impurities and then naturally dried during 3 days in order to reduce water content. The Fibrillium meshes were separated in water into individual fibers. Petiole, Rachis and Bunch were cut into two or three pieces afterwards the samples were prepared according to the characterization experiment: as fibers, powders or small pieces.

2.2. Materials and methods

2.2.1. Morphological analysis

Microscopic examinations of the samples were carried out using a JEOL/EO JSM-6390L scanning electron microscope (SEM). Energy dispersive spectroscopy (EDS) was used to analyze the chemical composition of the date palm samples using JEOL/EO JSM-6390L.

2.2.2. Physical analysis

The bulk density of samples was measured under the following climatic conditions, $T = 25 \pm 2\,^{\circ}$C and $RH = 65 \pm 2$ %, by the gravimetric method, according to NF EN ISO 1973 standard [9], on a balance with a precision of $\pm 0.1\%$. The absolute density of fibers was measured by Le Chatelier's volumeter method. Water absorption of the samples was measured in accordance to ASTM C127/88 standard.

2.2.3. Mechanical analysis

Modulus of elasticity of the DPF was determined in accordance to NF EN ISO 5079 [10], under the following climatic conditions, $T = 20 \pm 2\,^{\circ}$C and $RH = 65 \pm 2$ %, using an universal electromechanical testing machine WDW. Five single fibers for each part of palm tree residues were tested. Tensile test lengths were chosen to be 100 mm for all the samples and crosshead speed of 1 mm/min was employed.

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3. Results and discussion

3.1. Surface morphology

Figure 1 presents the SEM micrograph of typical surfaces of date palm fibers: (a) PF, (b) FF, (c) RF, (d) BF. It can be seen that the surface of all samples is dense and irregular. It is constituted by fiber beams and grooves with many little pores and fibrils. The same observations are also reported in the literature, concerning Fibrillium fibers [8, 11] and petiole fibers [12]. This morphology is expected to result in a better and more stable bond between fibers and the matrix [13].

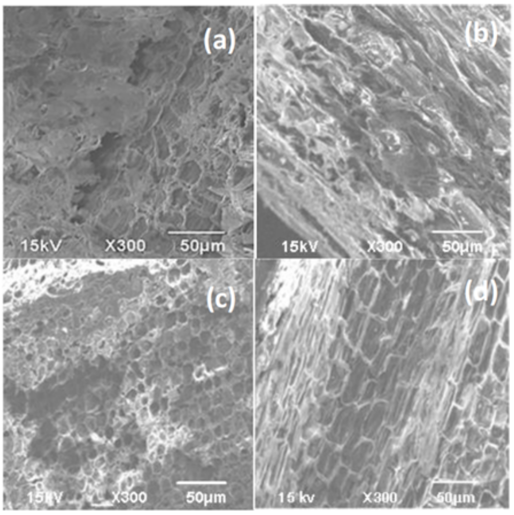

Fig. 1. SEM micrograph of typical surfaces of date palm fibers: (a) PF, (b) FF, (c) RF, (d) BF.

The elemental composition of date palm samples was determined and results are summarized in Table I. It was found that carbon and oxygen were the only consistent components in these materials. It can be also noted that the amount of the carbon is relatively high in Fibrillium, compared with the other samples and is lower, when compared with the results obtained by the authors of [14], in the same variety. This can be attributed to the chemical composition of the soil environment in which the plants are growing. Other minor constituents in trace quantities, which were obtained from the analysis, have included sodium, magnesium, potassium, calcium, etc.

3.2. Physical properties

Table II presents the physical properties of the four types of date palm wood. The results indicate that Petiole and Fibrillium had a lower density compared to other parts and even other natural fibers [15]. The mean percentage of water, absorbed by mass of Petiole and Fibrillium, ranges between 230% for sisal and 100% for coconut, according to results reported by Tolêdo Filho et al. [16], relating to sisal and coconut fibers. However, the mean percentage of water absorbed by mass of Bunch and Rachis is lower than that of coconut. This could have a beneficial effect on the fiber-matrix interface.

Chemical composition of typical samples of date palm wood. TABLE I

Element	Petiole [wt.%]	Rachis [wt.%]	Bunch [wt.%]	Fibrillium [wt.%]
C	40.15	43.65	41.08	61.24
O	49.80	40.30	50.30	32.05
H	2.18	6.40	5.04	5.20
Mg	0.342	0.290	0.041	0.082
Ca	0.526	1.469	0.289	0.313
K	0.168	0.442	1.452	0.006
P	0.095	0.195	0.135	0.128
Na	0.020	0.029	0.033	0.096
Fe	0.0016	0.0016	0.003	0.0107
Zn	0.0006	0.0136	0.004	0.0027
Mn	0.0009	0.0007	0.0003	0.0003
Cu	0.0006	0.0006	0.0004	0.0006

Physical properties of typical samples of date palm wood. TABLE II

Type	Bulk density [g/cm^3]	Absolute density [g/cm^3]	Water absorption [%]
Petiole	0.160 ± 0.54	0.995 ± 0.32	146.32 ± 20.40
Rachis	0.635 ± 0.22	0.857 ± 0.37	36.88 ± 10.15
Bunch	0.555 ± 0.11	0.838 ± 0.32	63.25 ± 5.00
Fibrillium	0.209 ± 0.31	0.976 ± 0.33	115.11 ± 15.7

3.3. Mechanical properties

Figure 2 presents the average Young modulus of Petiole (PF), Rachis (RF), Bunch (BF) and Fibrillium (FF) fibers. By comparing to the average Young modulus of other natural fibers, it can be seen that Rachis' and Petiole's Young moduli are close to that of coconut fibers and are considerably lower than those of most vegetable fibers reported in literature [16, 17]. This can be explained by the chemical and physical structure [18] of the natural fibers. However, when the specific modulus is considered (Fig. 3), the date palm tree fibers show values which are comparable or better than those of other natural fibers.

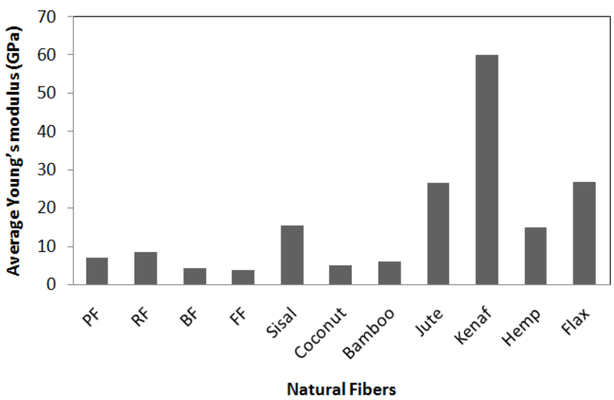

Fig. 2. Average Young modulus of DPF, compared to other natural fibers.

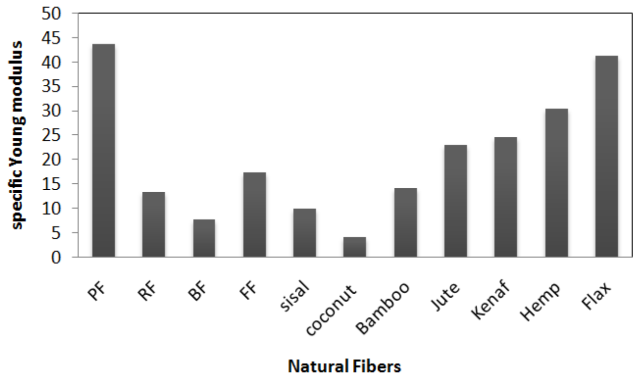

Fig. 3. Specific Young modulus of DPF, compared to other natural fibers.

4. Conclusions

In this work four biomass residues of date palm trees from Biskra Oasis were characterized in order to help to use them efficiently in composites. This preliminary investigation shows that Rachis and Petiole fibers have the highest value of Young modulus, compared to those in other tested wood types. Their use as composites reinforcement would be more profitable. Regarding the mechanical properties of more common vegetable fibers, date palm fibers have weak average of Young modulus and they are close to that of coconut fibers. But when considering the specific Young modulus, date palm tree residues show better values than those of other natural fibers. This property would be useful in applications which require at the same time a high strength and a light weight. Therefore, date palm wood is a good candidate for realization of natural fiber composites with several applications: building materials, automobile and furniture industries. Nevertheless, like other natural fibers, date palm fibers have to be pretreated to produce moisture repellency and resistance to environmental effects and consequently to improve the mechanical properties.

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