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Date palm wood flour as filler of linear low-density polyethylene

Seyed Mohammad Mirmehdi [a], Farhad Zeinaly [b,*], Fatemeh Dabbagh [a]

[a] Department of Wood Composites, Faculty of Wood & Paper Engineering, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran
[b] Young Researchers and Elite Club, Gorgan Branch, Islamic Azad University, Gorgan, Iran

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ABSTRACT

The effect of the filler content and the different type of wood flour on the mechanical properties of polyethylene composites filled with an agricultural pruning residue, date palm wood flour (DPWF) was studied. The different types of DPWF were rachis, leaflet and leaf, resulting from that annual pruning of date palm tree. Composites were made at 45%, 60% and 75% by weight wood flour contents. The particle size was 25–40 mesh and Maleic Anhydride modified polyethylene was also added at 2% of total weight of each board. First, the palletized feedstock from DPWF and plastic were provided by a twin screw extruder and then, the compound pellets ground and the final boards were made of them by a hot-press. It was observed that by increasing the filler content, the mechanical properties, flexural strength (MOR) and tensile strength decreased, while the flexural modulus (MOE) increased. The tensile strength did not show significant differences as a function of the filler type while the flexural strength and the flexural modulus of the boards made from leaflet flour, was the highest.

1. Introduction

Common wood–plastic composite is composed of wood or other lignocellulosic materials and virgin or waste thermoplastics. Lignocellulosic as powder or fibers are mixed to a dough-like consistency and then extruded or molded to the desired shape. Additives such as colorants, coupling agents, stabilizers, blowing agents, reinforcing agents, foaming agents and lubricants help tailor the end product to the target area of application. The material is formed into both solid and hollow profiles or into injection molded parts and products [1]. This differs from traditional wood composites where thermosets glues are used to assemble wood components into a product.

On the other hand, any substance that contains both cellulose and lignin is a lignocellulosic. Lignocellulosic include wood agricultural crops, like kenaf; agricultural residues, such as bagasse or corn stalks, agricultural pruning residue such as date palm fronds resulting from the annual pruning of date palm tree and other plant substances. In general, what is true for wood is also true for other lignocellulosics even though they may differ in chemical composition and matrix morphology, in fact natural fibers are available in many different forms and produce different properties when added to thermoplastics [2–4].

Contrary to natural fibers in recent years, the use of wood flour, the most common wood-derived filler for thermoplastics, in the manufacture of wood–plastic composites has been of great interest to many researchers. Wood flour is cheaper than wood fiber. In general, wood flour is used as filler for plastic, which tends to increase the stiffness of the composite but does not improve its strength. Natural fibers can be used to reinforce rather than fill plastics, which increase strength as well as stiffness. Wood and other lignocellulosic fibers typically have higher aspect ratio than that of wood flour. Furthermore, the aspect ratio of the fiber can be increased. At a critical fiber length, stress is transferred from the matrix to the fiber, resulting in a stronger composite [5]. Although most WPC products are considerably less stiff than solid wood, adding wood flour to unfilled plastics can greatly stiffen the plastic, but often makes more brittle, compared with pure plastics [6].

The convenience of these composites lies in the fact that one of their ingredients (i.e. wood/lignocellulosic material) can be easily obtained from natural resource and they can be made relatively easily [7]. The greater use of plastics and lignocellulosic materials would contribute to the conservation of the limited wood based resources. Moreover, absence of residues or toxic byproducts, whereas inorganic materials such as glass fiber, carbon fiber, talc, clay and synthetic fiber do not have these benefits [8]. There are many advantages to using wood-derived filler rather than mineral fillers in thermoplastics. Wood-derived fillers have greater deformability when compared to mineral fillers, which result in less filler damage during processing and less abrasiveness to equipment [9].

Since wood flour can contain as much as 8% moisture, it needs to be dried before it is mixed with the plastic. Embossing rollers and brushers are sometimes used to produce various surface

* Corresponding author. Tel.: +98 9125657146; fax: +98 1714427176.
E-mail address: farhad.zeinaly@yahoo.com (F. Zeinaly).

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textures for appearance and anti-slip purposes. One advantage of wood flour over that of convential mineral fillers, such as talc, is the lower density of the wood (about 1.4 g/cc for wood vs 2.7 g/cc for talk and calcium carbonate). There is also a high level of interest in using non-wood cellulose fibers derived from agricultural feed stocks such as flax, hemp, sugarcane fibers, kenaf, and peanut shells. Although some of these fillers are more expensive than that of wood flour, the longer aspect ratio of these fibers can lead to much better properties in the final WPC product.

The mechanical properties of wood fiber composites may not be significantly affected by wood fiber type [10], but it has also been reported that the type of lignocellulosic fiber and the lignin, cellulose and hemicelluloses content have a strong influence on mechanical properties [11].

From an economical point of view, wood-derived fillers come from a renewable resource and are typically less expensive than mineral fillers [12].

Middle East is the major producer of dates in the world and after Egypt and Saudi Arabia; Iran is on the third place of top ten date's producers in this area [13].

The objective of this study were to evaluate mechanical properties of the date palm wood flour (DPWF)/LLDPE composites and the influence of the filler level and the different type of DPWF on the mechanical properties.

2. Materials

2.1. Matrix polymer

The thermoplastic polymer, linear low density polyethylene (LLDPE), LL0220CA (off-grade), with a melt flow index of 2–2.5 g/10 min (190 °C, 2.16 kg) and a density of 0.917–0.920 g/cm^3 and with a melting temperature of 150 °C, was used as the powder polymer matrix and obtained from Arak Petrochemical Corporation. Melting point was determined employing differential scanning calorimetry method (DSC) according to ASTM D3418.

2.2. Filler

The date palm wood flour used as a filler was obtained from a different parts of date palm tree, rachis, leaflet and leaf, resulting from the annual pruning of date palm tree (Fig. 1) (Sayer cultivar from khoozestan, Iran) at 45%, 60% and 75% by weight used as the discontinuous phase (filler or reinforcement) in the composites and their size was 25–40 mesh.

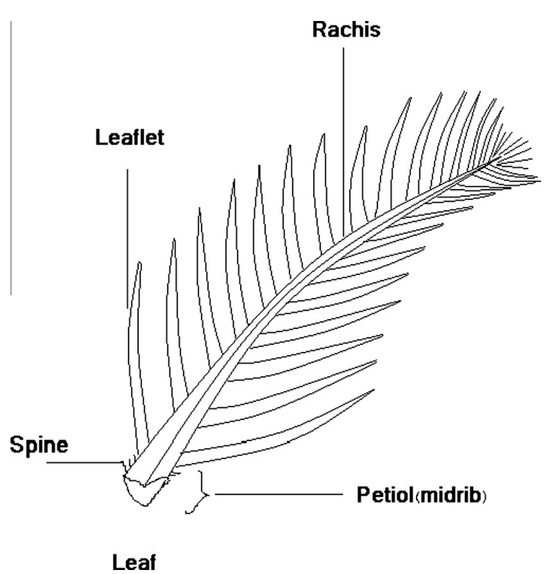

Fig. 1. Structural parts of date palm tree.

Before grinding, the date palm tree pruning residue left 3 months in subject of air to reach equilibrium moisture content and then was ground with a chipper and then the particle was ground with a small laboratory grinder followed by passing through a 25-mesh screen and remaining on the 40-mesh screen and then was oven-dried at 100 ± 5 °C for 24 h to expel moisture and then was stored in sealed plastic bags prior to compounding. Tables 1 and 2 present the average of chemical constituent of different parts of date palm tree frond and their fiber properties.

2.3. Compatibilizing agent

The campatibilizing agent, polyethylene Maleic Anhydride, MAPE with a fixed amount 2 wt.% was used in the sample preparation because it was the best recommended amount in previous research. MAPE was used to obtain better bonding between the hydrophilic and the hydrophobic matrix polymer. Maleated polyolefins are usually used at 1–5% by weight in a WPC formulation. It is very important to understand that just adding the "right" amount of a coupling agent will not necessarily improve properties of the WPC material. It is really important to highlight the significance of optimizing the manufacturing conditions, as well as the other additives in the formulation. Furthermore, it is very difficult to compare different sets of data from WPC boards made by different groups of people, using different production equipment, operated at different manufacturing speeds, with different coupling agents, and at their different levels [14].

3. Experimental

3.1. Compounding

Polymer, fillers, and compatibilizer were initially weighed and bagged according to the various filler contents indicated in Table 3.

After weighing the required quantity of materials for each treatment, DPWF/LLDPE composites were prepared in a twin-screw extruder, model 4815, L/D ratio 21, at 7 rpm and the temperature profile of 150, 150, 145, 145, 150 and 145 °C at zones 1, 2, 3, 4, 5, 6 and 7 (die zones), respectively.

LDPE typically has long side-chain branching off the main molecular chain and therefore is a more amorphous polymer. It has a relatively low-melting temperature (typically between 106 and 130 °C, depending on density/branching of PE) [14]. Linear low-density polyethylene (LLDPE) differs structurally from conventional low-density polyethylene (LDPE) because of the absence of long chain branching. Melting temperature range of LLDPE is between 120 and 160 °C [13].

The composites were granulated and dried at 103 ± 2 °C for 24 h to eliminate residual humidity from the fiber and stored in sealed packs containing a desiccant to avoid unexpected moisture infiltration before hot-press forming (Table 4). Three panels were produced for each parameter (three replicate) in the laboratory. To prepare the composites, each mixture was separately spread as randomly as possible inside a metal frame and a wooden box with dimensions 20 cm by 15 cm by 0.5 cm in order to form a mat. This

Table 1
Chemical constituents of the different parts of date pam tree fronds.

	Cellulose	Hemicelluloses	Lignin	Ash	Extractive
Leaflet	40.21	12.8	32.2	10.54	4.25
Rachis	38.26	28.17	22.53	5.96	5.08