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Mechanical and acoustical properties of particleboards made with date palm branches and vermiculite

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ABSTRACT

The main goal of this study was to determine the performance of particleboards made from date palm branches (DPB, *Phoenix dactylifera*), as a low-value raw material and expanded vermiculite (VER), as a natural inorganic filler. DPB is underutilized abundant byproduct in southern parts of Iran. For the purpose of evaluation, compositions of DPB and VER at different mixture rates were compared for some properties. Variable parameters were: number of particleboard layers (single- and three-layer), VER size (micro and nano meter), and VER content (0, 10 and 20 wt%). Other parameters such as resin content (10%), hardener content (2%), pressing time (6 min), board density (0.75 g/cm^3), press pressure (35 kg/m^2) and press temperature (175 °C) were held constant. Physical properties (thickness swelling (TS), water absorption (WA), and sound absorption coefficient (SAC)), and mechanical properties (modulus of rupture (MOR), modulus of elasticity (MOE), and internal bond strength (IB)) of the boards were determined. Based on the findings of this study, all mechanical properties of the boards slightly decreased when the VER content was increased from 0 to 20 wt%. Analysis of data revealed that the mechanical properties were significantly different among the board types. In general, WA and TS increased with the increase of WER content. The presence of nano VER in the particleboards resulted in higher WA and TS. The SACs of composite boards filled with VER increased as the frequency increased. Nano VER and single-layer boards showed higher SACs in frequency range of 800–1250 Hz. Finally, it can be stated that DPB has potential as replacement fibrous material for particleboard manufacturing and indoor applications.

1. Introduction

Particleboards have become the most popular wood-based composites because they enable wood particles from relatively low quality materials to be transformed into useful large wooden panels, providing both environmental and economical benefits [1]. Particleboards are manufactured from particles of wood or other fibrous materials, which are formed and pressed together using an organic binder together with one or more of agents, such as heat, pressure, catalyst, and so on [2]. The primary lignocellulosic material used in the particleboard industry is wood. However, the manufacture of particleboard is the most common way to reuse waste materials [3]. Serious shortage of wood resources in developing countries, including Iran, has created interest to explore the potential application of agro-waste based composites for the wood industries. Çöpür et al. [4] believe that agricultural byproducts are excellent alternative waste materials to substitute wood because they are plentiful, widespread, and easily available. Apart from their abundance and renewability, utilization of agro-wastes can be advantageous to socioeconomy, environment, and technology. Research has been carried out on a wide variety of agro residues from many different regions of the world: sunflower stalks [5], wheat-cereal straws [6], rice straw [7], bagasse [8], rapeseed straw [9], oil palm [10], and cotton carpel [11]. According to these studies, with the combination of wood chips, modification of agro-wastes, and the addition of some moisture repellant, it is feasible to produce particleboards, which have the physical and mechanical properties as required by related standards. Several countries utilize agro-wastes for the production of particleboards or other composite panels. So far there are at least 30 plants that utilize agro-waste materials in the production of particleboards around the world [12].

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The highly hydrophilic characters of lignocellulosic materials make them incompatible with thermoplastics which are highly hydrophobic. Such incompatibility produces poor interfacial adhesion between matrix and filler, which results in poor mechanical property because stress can not be transferred properly from the matrix to the fibers. The incorporation of nanoparticles as reinforcing filler is a method for improving the overall properties of wood-based composites [13–15]. Investigations on the effect of nanoparticles on the final properties of particleboards made from lignocellulosic materials have also been the point of interest. Nanoparticles are described to be high potential filler materials for improving physical and mechanical properties of wood-based composites [16]. A number of studies have reported the effects of nano particles such as zinc, silver, clay, and wollastonite on mechanical properties of particleboard [17]. Recently, vermiculite (VER) has been proved to be a promising reinforcing agent for biopolymer composites [18–21]. VER is a lightweight material with porous, inexpensive, ecologically harmless, non-toxic and expandable as much as 8–30 times its original size, when heated to about 800 °C. It is a natural hydrous magnesium silicate mineral with $(Mg, Ca)_{0.7}(Mg, Fe, Al)_{6.0}[(Al, Si)_{8.0}](OH_{4.8}H_2O)$ as the theoretical unit cell formula. VER belongs to the 2: 1 layered structure composed of two tetrahedral silica sheets enclosing a central sheet of octahedral magnesia [22]. Adjoining layers are held together by a combination of electrostatic and van der Waals forces [23]. Furthermore, the increased presence of silanol groups on VER surface is noteworthy, which easily establish strong hydrogen bond interactions with hydroxyl groups in bipolymers such as cellulose and chitosan.

The main objective of this study is to use date palm (*Phoenix dactylifera* L.) branches (DPB, as agro-waste) and vermiculite (as inorganic filler) for laboratory made particleboards, and to test selected properties of the boards to determine if they have the required levels of properties for general uses. It is to be noted that both DPB and VER are abundant and cheap in Iran and VER has larger cation exchange capacity (CEC) when compared to montmorillonite [22]. To the best of our knowledge, no published reports are available regarding the effect of vermiculite on the physicomechanical properties of particleboards.

2. Materials and methods

2.1. Materials

Several kilograms of freshly pruned date palm branches (DPBs), from the Kerman Provience (Iran), were used in this investigation. Midribs from defoliated DPBs were initially cut into suitable lengths and air-dried to reduce the water content prior to mechanical processing. Air-dried DPBs were cut by hand into pieces of 30–40 cm and then reduced further with a hammer mill to approximately 15 mm in length, 2 mm in width and 0.4 mm in thickness (Fig. 1a). Particles were oven-dried at 103 °C for 5 h to a moisture content of less than 4% prior to processing.

Urea formaldehyde (UF) adhesive with a solid content of 63%, density of 1.28 g cm^{-3}, viscosity of 45 cp, gelation time of 67 s, and pH of 7.5 was applied. As a hardener, ammonium chloride (NH_4Cl) solution (solid content: 20%) was added to the adhesive.

The commercial available sample of expanded vermiculite (VER) was obtained from Zarin Mikai Alboroz Co. (Iran). The chemical composition of the used VER is shown in Table 1. Fig. 1(b–d) shows the VER as micro and nano size, respectively.

The VER (100 g) was ground in a planetary ball mill at 1000 rpm using Si_3N_4 balls (Ø10 mm) for 4 h.

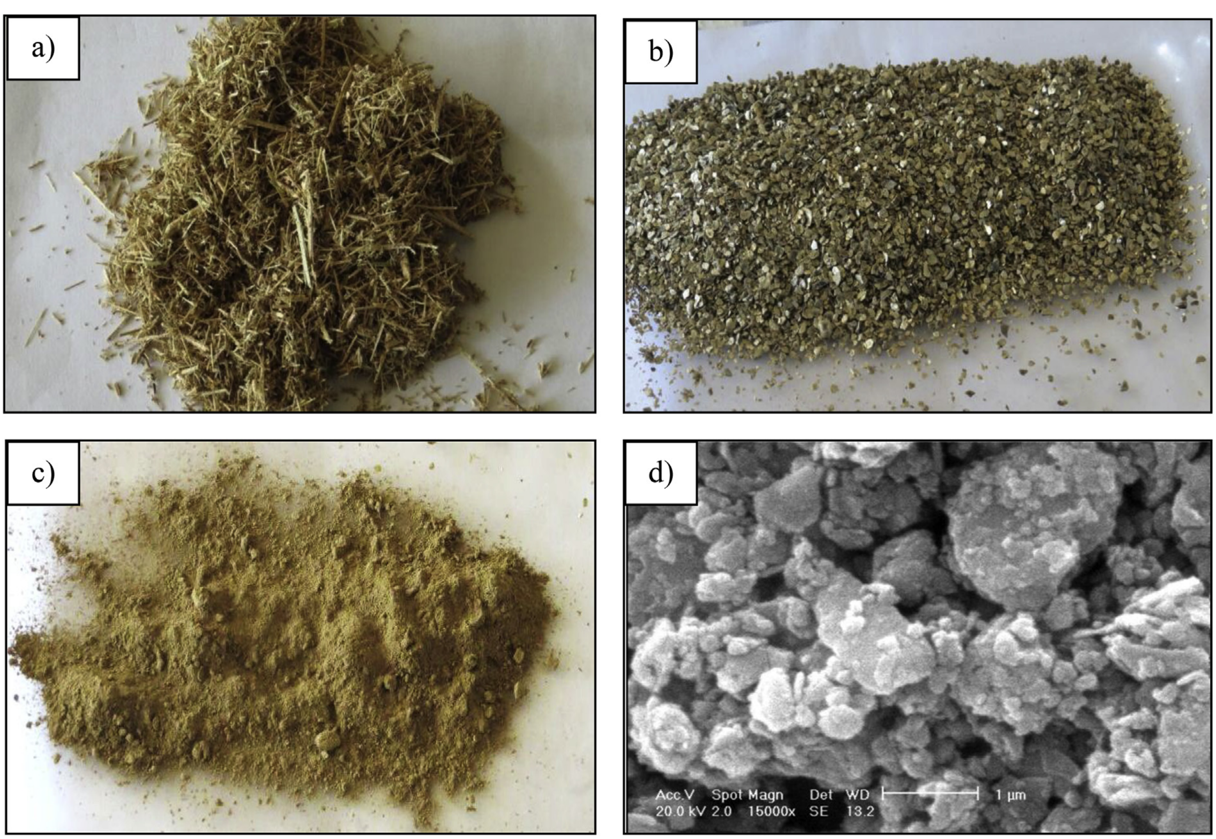

Fig. 1. (a) Particels of DPBs, (b) micro particles of VER, (c) nano powder of VER, and (d) SEM micrographs of nano VER.