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Research paper

Particleboard from wood particles and sycamore leaves: Physico-mechanical properties

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ABSTRACT

The aim of this study was to evaluate the physical and mechanical properties of particleboards manufactured from mixture of sycamore leaves and wood particles. Five panel types were made from mixtures of wood particles/sycamore leave (100/0, 90/10, 80/20, 70/30 and 60/40%, respectively). Some mechanical (modulus of rupture, modulus of elasticity and internal bonding strength) and physical properties (thickness swelling and water absorption) of the particleboards were determined. The results show that with incorporation of sycamore leaves up to 20%, the mechanical and physical properties of resulting particleboards improves. Nevertheless, the mechanical properties of all the panels exceed the minimum requirements of EN Standards for furniture manufacturing. Using renewable bio materials like sycamore leaves for manufacturing particleboards could contribute solution of raw material shortage for particleboard industry, decreasing the pressure on forest resources and diminishing environmental problems regarding their burning.

1. Introduction

The growing demand for wood based panels as a result of increasing population of the world which adversely influences sustainable utilization of forest resources has led to continuous efforts to find new resources as an alternative to wood (Ayrilmis et al., 2009a). Successful development of wood composite panels in the last decades could be attributed to the economic advantage of low-cost wood and other lignocellulosic raw material and inexpensive processing with various types of binders (Kalaycioglu et al., 2005). 57% of total consumption of wood-based composites belongs to particleboard and it is continuously growing at 2–5% annually (Ashori and Nourbakhsh, 2008). With the increasing consumption of woody raw materials, their substitution seems inevitable. Alternative raw material such as underutilized species, fast-growing species, agricultural crops, and other plant fibers will play an important role in providing balance between supply and demand (Salari et al., 2013). Advantages of bio material over synthetic counterparts are their low cost, high toughness, low density, good specific strength properties, good processability and biodegradability (Sarki et al., 2011). A good selection of agricultural residues including wheat straw, sugarcane, sunflower seed hull, bamboo and palm have been successfully used in particleboard manufacturing and are already in the market under different trade names (Ciannamea et al., 2010).

One of the underutilized bio based resource is tree leaves with the potential of providing a non-food based market for particleboard industry. The world's total forest area is just over 4 billion hectares, or 31 percent of the total land area (FAOSTAT, 2012). Total biomass yield and the leaf proportion vary with species and varieties. Fresh leaf yields of 40 ton/ha/year (nearly 10 tons of dry matter) have been reported for some species in Costa Rica (Espinoza et al., 1999). In the forest, leaves fall to the ground and can be both beneficial (become food for numerous soil organisms vital to the forest ecosystem (Campanella et al., 2013) or detrimental, ignition point in wildfires (Ozkaya et al., 2013) and soil metal concentration concerns (Heckman and Kluchinski, 1996)). Foliage biomass, fuel depth, fuel bulk density and foliage retention are of important indices in prediction of fire behavior properties in forests (Bilgili, 2003). In cities and towns leaves are predominantly considered a waste; they are collected and burned and in rare cases are composted (Campanella et al., 2013) and in villages usually are used by farmers as a ruminant roughage source for cows (Ozkaya

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et al., 2013). Only in the United States, there are 30 million tons of leaves that are collected and burned every year (Campanella et al., 2013). In some countries burning of leaves in populated areas as well as municipal leaf deposal in sanitary landfills are prohibited (Heckman and Kluchinski, 1996). They tend to burn slowly and consequently generating large amounts of airborne particulates (fine bits of dust, soot and other solid materials) they can cause health problems and may also contain hazardous chemicals such as carbon monoxide (Campanella et al., 2013).

The leaves have a waxy epidermal surface layer (Campanella et al., 2013). The hydrophobic layer primarily includes all kind of extractives (wax, inorganic silicon, and fat), which could weaken the compatibility between water-based adhesives and waxy materials (Zheng et al., 2009). UF is water based wood adhesive that of its shortcomings, low efficiency, poor water resistance and formaldehyde emission can be mentioned (Dunky and Pizzi, 2002). Because of the similar reason, other water-based adhesives, including protein and starch based adhesives, are also not effective to bond grass-based particleboards directly (Zheng et al., 2009). On the other hand, MDI resin can perfectly bond agricultural wastes to wood fibers (Yang and Zhang, 2004). MDI adhesives are also capable of forming covalent urethane bonds with wood to enhance bond line durability (Abdolzadeh et al., 2011). The cost of PMDI is about 7–10 times higher than that of UF (Zheng et al., 2009). However, 4% of isocyanate gives panels the results which are comparable to those of boards bonded with 8% of a phenolic resin (Dunky and Pizzi, 2002) and 7% of a phenolic resin gives panels the results which are comparable to those of boards bonded with 10% of UF (Doosthoseini, 2002).

Aghakhani et al. (2013) investigated the physical and mechanical properties of sycamore leaves based panels and effect of production parameters on the resulting panels. They found that mechanical properties of the sycamore leaves based panels exceed the requirements of EN Standards and density and press time were the main parameters influencing the physical and mechanical properties of the resulting panels. There is no information about the utilization of sycamore leaves in mixture with wood particles in the manufacture of particleboard. The objective of this study was to investigate the suitability of sycamore leaves in production of particleboard as a supplement and to alleviate the shortage of raw material in forest industry as well as to test the mechanical and physical properties of panels to determine if they have required levels of properties for general uses.

2. Material and methods

The raw material of this study included industrial wood particles, and consisted of industrial wood particles (mixed hardwood species such as hornbeam, beech and oak) that was provided by a commercial particleboard plant in Gorgan, Iran and leaves obtained in the fall season from sycamore trees (*Platanus orientalis*) (Fig. 1) were first cleaned of dirt and impurities and then chopped using a blender (Suny pro-classic food processor) without any treatments.

Methylene diphenyl diisocyanate (MDI) with characteristics given in Table 1 was provided from Baspar Shimi, Iran and used at a level of 4 wt% for manufacturing three-layer particleboards.

Next the chipped leaves and wood particles were classified in laboratory shaker. Particles that remained between 3–1.5 mm sieve and 1.5–0.8 mm sieve were utilized in the core and outer layers, respectively. Particles were oven dried at 100 ± 3 °C to reach the target moisture content. The particles were placed in a drum mixer and blended with MDI. The particles then were pressed into panel mat using a laboratory scale hydraulic hot press (OTT, Germany). Aluminum foil was applied on the MDI-mat to avoid the adhesive sticking to the hot press plates. The suitable moisture content of the

Fig. 1. Sycamore leaves on the ground of a park.

Table 1
Properties of the MDI adhesive.

Properties	MDI[a]
Solid (%)	100
Density (g/cm^3)	1.273
Viscosity (cps)	300
Gel point (100 °C)	–

[a] Methylene diphenyl diisocyanate.

MDI-mat for particleboard manufacturing was adjusted at 8% (Abdolzadeh et al., 2011). Since MDI resin contains no water, prior to mat fabrication, some water was added to the leaves particles to obtain the necessary MDI mat moisture content. Thickness of panels was controlled by stop bars and panels target density was 0.7 g/cm^3. Three panels were produced for each group. The experimental design is shown in Table 2.

The dimensions of the produced particleboards were 420 × 420 × 16 mm. The produced particleboards conditioned at 20 °C and 65% relative humidity to reach moisture content of about 12% before trimming to final dimension of 400 × 400 × 16 mm. The panel production parameters were also displayed in Table 3.

The flexural properties (modulus of rupture (MOR) and modulus of elasticity (MOE)) of the samples conditioned at 20 °C and 65% relative humidity (RH) were performed according to EN 310 (1993). A total of ten replicate samples with dimensions of 250 mm × 50 mm × 16 mm were tested for each type of particleboard. The flexural tests were conducted in accordance with the third point loading method. The samples were tested on Instron testing machine equipped with a load cell with a capacity of 10 KN. The internal bond (IB) strength tests were conducted on the

Table 2
Experimental design.

Board type[a]	Raw material	
	Sycamore leaves (%)	Wood (%)
A	0	100
B	10	90
C	20	80
D	30	70
E	40	60

[a] The density of the boards made from sycamore and wood chips was 0.70 g/cm^3.

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