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PROPERTIES OF WOOD-STRAW COMPOSITES BONDED WITH MODIFIED UF ADHESIVE AND PRE-TREATED STRAW PARTICLES

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Abstract:
The paper presents the effect of some non-expensive treatments applied before the particleboards production under two instances, in one case by adding ethanol to the UF resin and in other cases by boiling the straw particles, with a view to improve the bonding quality of the mixed wood-straw composites. The modulus of rupture (MOR) and tensile strength perpendicular to the surface (IB) were evaluated. Mechanical performance of wood-straw particleboards bonded with the UF modified glue by ethanol and that one of the particleboards manufactured from pre-treated straw raw material by boiling in soapy solution met the standard requirements. The results of this study show the potential of such agro-wastes for the particleboards manufacturing.

Key words: *wood-straw particleboards; wheat straw; wood particles; urea formaldehyde.*

INTRODUCTION

Particleboard is one of the most used materials for constructions, furniture, cabinetry, walls, flooring, and other aesthetic architectural applications. A great interest was shown the last decades to sustainable materials, approach that brings to light the use of various wastes, such as vegetable agro-waste to produce new materials. Therefore the use of conventional wooden material for particleboards has shifted to the use of renewable resources (Cuk *et al*. 2011). Even there have been few limitations connected to the lack of chemical knowledge and properties of these agro-materials, over the years wood chips have been substituted in particleboards production by particles obtained from annual plants, such as: wheat straw, rice straw, tea leaves, coconut chips, flax, hemp, kenaf, bamboo, bagasse, almond shell, corn peel, sunflower, sugar cane, and rapeseed, just to name a few (Boquillon *et al*. 2004; Dukarska *et al*. 2016; Guler *et al*. 2016; Guru *et al*. 2006; Han *et al*. 1998; Kalaycioglu and Nemli 2006; Li *et al*. 2010; Papadopoulos and Hague 2003; Xu *et al*. 2004; Yalinkilic *et al*. 1998).

According to FAO, the world cereal production went along with its utilization and stocks reaching more than 2400 million tons in 2016, out of which a total of 760.1 million tons was recorded for wheat production. Wheat straw is still one of the most abundant and cheap agro-waste materials in the world. The wheat straw is currently used in some limited applications: feed stuff, fertilizer, pulp industry, nano-materials, and for bio-ethanol also in pyrolysis, combustion and gasification (Talebnia *et al*. 2010). In Ukraine the wheat straw is considered by far the most perspective raw material suitable and very attractive to be used for particleboards manufacturing (Bekhta 2007).

Ukraine has been rated in 2011 among the top ten countries of wheat production and consumption per capita, and exports as well (FAO). According to The State Statistics Committee in 2015 the grain production in Ukraine was the third highest ever. In general, previous three years were the most productive throughout the history of Ukraine. Also the forecast for the crop production in 2016/17 was estimated at 24 million tons due to the favorable spring weather that has greatly improved the wheat yield prospects. Nowadays straw and other agricultural residues represent the most important sources of biomass for energy in Ukraine.

Since 2010 straw has been used for the production of pellets and briquettes (Geletukha *et al*. 2015). There are big amounts of wheat straw residues which are still burnt in the field causing significant environmental problems apart the loss of a valuable resource (Bekhta *et al*. 2013).

Wheat straw fiber and wood present different morphological features and mechanical properties, and in general they have a similar chemical composition, containing cellulose, hemicellulose, lignin and some extractives. The high content of silica in wheat straw leads to greater power consumption and also limits the service life of the crushing equipment. The fat-wax surface layer worsens wetting and gluing and it influences the adhesion between particles and represents a major obstacle for the particleboards production.

The quality of bonding may be improved when removing the fat-wax layer by using some physical and chemical processes (Bekhta *et al*. 2011) or with glues having greater reactivity instead of urea formaldehyde (UF) glue (Pease 1998; Grigoriou 2000; Zhang *et al*. 2011). Although it has some disadvantages, such as formaldehyde emissions it appeared that UF is still the most economical, due to its low cost and easy production, although it produces a low bonding with the straw particles (Guru et al. 2006). But the bonding quality of wheat straw with UF resin may be improved by applying several treatments either to the raw material or to the adhesive itself (Bekhta and Kozak 2011; Bekhta *et al*. 2013).

OBJECTIVE

The paper presents the effect of some non-expensive treatments applied before the particleboards production under two instances, in one case to the UF resin by adding ethanol and in another case to the straw particles by boiling them, with a view to improve the bonding quality of the mixed wood-straw composites. The modulus of rupture (MOR) and tensile strength perpendicular to the surface (IB) were evaluated.

MATERIAL, METHOD, EQUIPMENT

Wood particles supplied by a particleboards producer and wheat straw resulted from a local farm in Ukraine were used to produce experimental particleboards. Stems of wheat straw were cut, crushed and dried at 4% MC while wood chips were used as they were supplied and dried separately at same moisture content. A commercial UF resin with a solid content of 65% and ammonium chloride as a hardener were used for the particleboards manufacturing. The same pressing schedule of the wood-straw particleboards was applied, such as: the temperature of 170°C and the pressure of 2.2MPa for 6min. The panels (300x300mm) were produced having the same target density of 650kg/m^3. Panels with no treatment were manufactured as control panels. The study cases as function of the pre-treatment applied before the particleboards manufacturing, in one case to the UF resin and in the other cases to the wheat raw material, are presented in Table 1. The experimental work was performed at the Department of Wood-Based Composites, Cellulose and Paper from the Ukrainian National Forestry University in Lviv, Ukraine.

Table 1

Schedule of the experimental work

Case and Treatment type	**Case A**	**Case B**	**Case C**
	UF resin modified by ethanol	**Pre-treatment applied to straw by boiling**	
Type of board and thickness	three-layered panel 16mm	single-layer panel 19mm	
Ratio between layers	20:60:20 (outer:inner:outer)	60% wood particles and 40% wheat straw	
Treatment	outer layers: wood particles + UF glue inner layer: wood and straw particles + modified UF glue (10 mass units of ethanol on 100 mass units of resin)	45 min- boiling in soapy solution of 20% concentration	45 min - boiling in water at 100°C

Prior to sampling the manufactured particleboards were kept in laboratory conditions at the temperature of 20ºC and 65% RH to reach the equilibrium moisture content. The modulus of rupture (MOR) and the tensile strength perpendicular to the surface (IB) were determined according to standards (BS EN 310 1993; BS EN 319 1993).

RESULTS AND DISCUSSION

The results for the mechanical properties (MOR and IB) obtained for all the cases under study are graphically displayed in Figs 1 and 2.

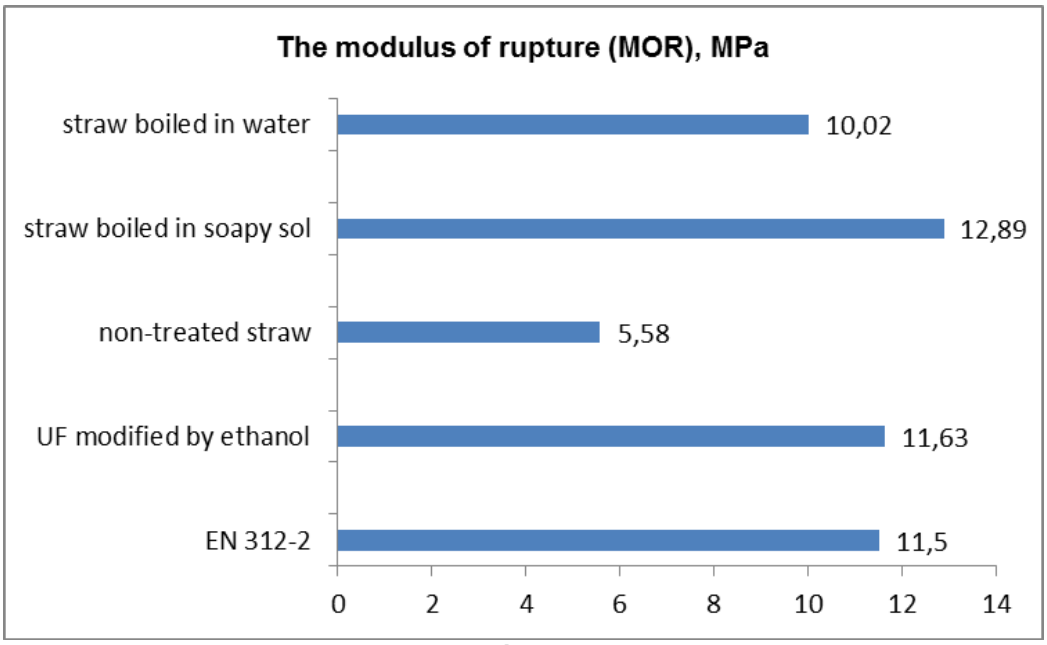

Fig. 1.
Modulus of rupture of wood-straw particleboards as function of different treatment applied before manufacturing.

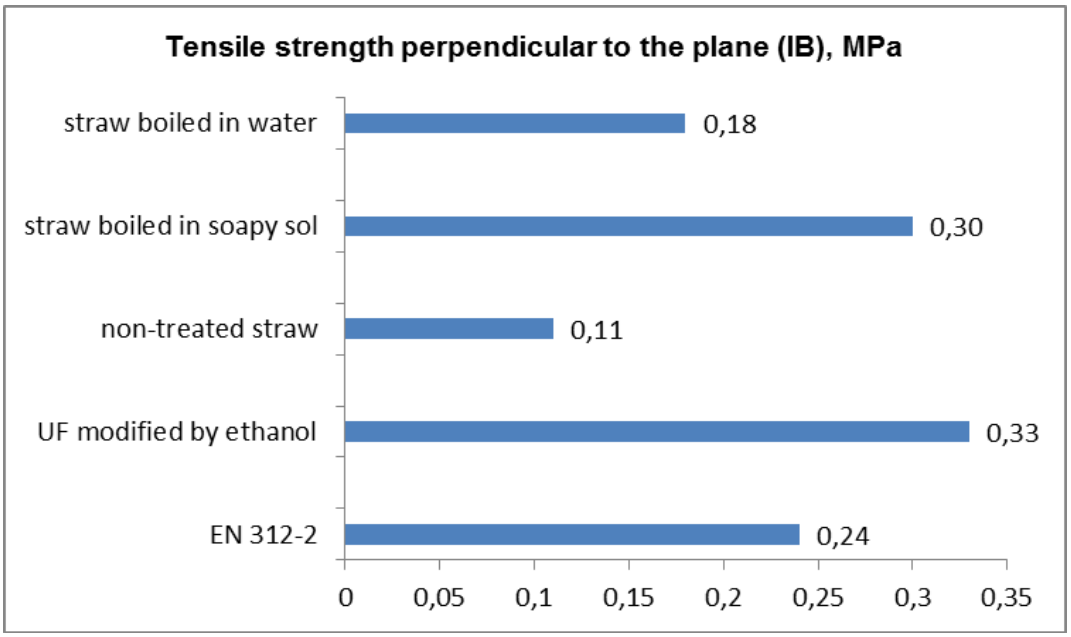

Fig. 2.
Tensile strength perpendicular to the surface of wood-straw particleboards as function of different treatment applied before manufacturing.

Case A - UF resin modified by ethanol

The results show that the wood-straw composites glued with modified UF resin by ethanol exhibited better properties when compared to those requested by standards specific to wood particleboards (EN 312 2003). The ethanol contained by the glue was expected to dissolve the fat-wax layer of straw during the particleboards manufacturing. Therefore it was assumed that the hydrophobic effect of fat-wax layer on the adhesive interaction with particles decreases. During the pressing step the ethanol evaporates from the boards together with the moisture (Kozak *et al*. 2016).

Cases B and C - Pre-treatment applied to straw by boiling (soapy solution and water)

Both types of mixed particleboards made of wheat straw particles boiled in a soapy solution and water showed increased MOR and IB values when compared to that of control samples. The treatments applied to the raw material improved the properties of the samples and such result may be related to the dissolution of silica in the raw material when being exposed in such conditions. The reduction of silica in the straw particles may positively influence the bonding quality and the distribution of glue on the particles. When compared to the requirements of EN standards (EN 312 2003) it appeared that only the composite panels made of wheat straw particles pre-treated by boiling in soapy solution met them.

Neither the control panels nor the boards made of boiled straw particles met those standard requirements. Therefore the pretreatment of straw particles with a soapy solution was found to be the most effective way to improve the mechanical properties of the wood-straw composites, such as the internal bond strength of the samples. Such result may be explained by the improved wettability of the raw material surface and consequently the subsequent improvement in adherence of UF resin and the hydroxyl groups of cellulose. The surface-active agents in the soapy solution contributed to the strong effect of the solution on the internal bonds in particleboards (Bekhta *et al*. 2013).

Similar results and conclusions from this work on the potential of such wood-agro-wastes particleboards were found by other authors in the field of composites (Boquillon *et al*. 2004; Mo *et al*. 2003; Zhang *et al*. 2011).

CONCLUSIONS

Mechanical performance of wood-straw particleboards bonded with the UF modified glue by ethanol and that one of the particleboards manufactured from pre-treated straw raw material by boiling in soapy solution met the standard requirements specific to particleboards.

The results of this study show the potential of agro-wastes for the particleboards manufacturing.

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