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COMPARATIVE CHARACTERISTICS OF EXPLOITATION PROPERTIES OF MDF MANUFACTURED WITH PARTICIPATION OF NON-WOOD LIGNOCELLULOSIC RAW MATERIALS

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ABSTRACT

Shortage of wood raw material and the considerable amounts of agricultural waste and residues are one of the main environmental challenges today, which justify the relevance of studying the possibilities of utilization of non-wood lignocellulosic raw materials in production of wood-based composites.

This article presents the study on the impact of including different non-wood lignocellulosic raw materials in the composition of MDF on their exploitation properties. Three types of non-wood lignocellulosic raw materials – maize stalks, industrial hemp stalks and thin bamboo stalks - were used for the purpose of the study. The materials were refined in laboratory conditions using defibrator disc mill. The panels were manufactured by using industrial wood-fibre mass and variation of non-wood raw materials from 10 to 40%. The main exploitation properties of MDF were determined and analysis on the possibilities of including the studied lignocellulosic raw materials in the composition of the panels was made.

Key words: MDF, maize stalks, industrial hemp stalks, bamboo stalks, exploitation properties

1. INTRODUCTION

The increasing shortage of wood raw material and growing consumption of wood-based panels (FAO) justify the relevance of studying the possibilities for utilization of non-wood annual and perennial lignocellulosic raw materials, representing agricultural waste and residues, in the production of woo-based composites.

A significant number of studies have been focused on utilization of lignocellulosic residues in the composition of particleboards. There are different studies about the possibilities of utilization of cotton stems (Mihailova, J. et al. 2006), raspberry stems (Todorov, T. et al. 2007), wheat stalks (Wang, D. et al. 2002) in the composition of particleboard, as well as comparative analyses of using different lignocellulosic raw materials (Mihailova, J. et al. 2008). Other studies have been conducted on the possibilities of using these raw materials in production of wood-cement panels (Mihailova, J. 2008), as well as on the suitability of particleboard manufactured with lignocellulosic raw materials for general, not load-bearing applications (Mihailova, J et.al. 2007).

The number of studies regarding the use of lignocellulosic raw materials in the production of MDF panels is significantly lower compared to particleboard manufacturing (Eroğlu H. et al. 2000; Gencer A, et al. 2001; Akgul, M et al. 2010; Mihailova, J et al. 2018a; Mihailova, J et al. 2018b). It should be noted that the global production of fibreboards exceeds the particleboard manufacturing.

Since 2012 the MDF/HDF production has been growing by 4% annually on average and has accounted for 83% of all fibreboard production in 2016 (FAO).

2. MATERIALS AND METHODS

The wood-fibre mass, used for production of MDF, was obtained in factory conditions of Welde Bulgaria AD – Troyan, according to the Asplund method. The wood-fibre mass had the following composition: beech and Turkey oak (60%), poplar (20%), and Scots pine (20%). The mass was dried in laboratory conditions to 10% moisture content.
Urea-formaldehyde resin, produced by Kastamonu Bulgaria AD, was used as a binder. The resin had an initial concentration of 58% and it was added to the wood-fibre mass at 50% concentration.
The non-wood lignocellulosic raw materials (maize, hemp and bamboo stalks) were refined on a disc mill with one rotating grinding disc, presented on Figure 1.

Figure 1. *Laboratory disc mill*

The mass produced from the different non-wood lignocellulosic raw materials was dried to the following water content: maize stalk mass – 9%, hemp stalk mass – 10%, bamboo stalk mass – 10%.
The addition of adhesive and water repellants was made using a high-speed glue blender with needle-like blades at 850 min^{-1} for 40 to 60 s. The hot pressing was performed on a laboratory press type PMC ST 100, Italy.

The pressing was carried out at 185 ± 5 ℃ hot pressing temperature and pressing time of 1 min/mm. A three-stage pressing regime was applied at the specific pressure, as follows: I stage - 2,5 MPa; II stage - 1,3 MPa; III stage - 0,6 MPa. The duration of the different stages was the following: I stage - 20% of the whole pressing cycle; II stage - 30% of the pressing cycle; III stage – 50% of the pressing cycle.

The panels were manufactured with thickness of 6 mm and density of 850 $kg.m^{-3}$. The physical and mechanical properties of the produced MDF panels were determined in accordance with the requirements of the respective EN standards (EN 310; EN 317 and EN 323).

3. RESULTS AND ANALYSES

The summarized results for the exploitation properties of MDF panels, produced with the different non-wood lignocellulosic raw materials, are presented in Table 1.

***Table 1.** Exploitation parameters of MDF panels produced at different content of non-wood lignocellulosic raw materials*

Panel No.	Non-wood raw material *Px*, %	Density *ρ*, $kg.m^{-3}$	Water absorption *A*, %	Swelling in thickness *Gt*, %	Bending strength *fm*, $N.mm^{-2}$
Maize stalk mass					
1.	10	852	68.61	16.86	37.76
2.	20	861	69.32	18.32	35.89
3.	30	848	73.52	23.77	34.49
4.	40	841	75.76	23.09	30.16
Hemp stalk mass					
5.	10	848	81.44	28.53	44.02
6.	20	854	85.78	29.53	43.99
7.	30	845	86.54	31.50	43.52
8.	40	858	89.13	32.96	42.96
Bamboo stalk mass					
9.	10	857	66.49	31.69	28.80
10.	20	863	64.87	32.74	27.77
11.	30	846	64.95	27.92	26.97
12.	40	845	63.74	27.02	24.72

The density of the obtained panels is very close to the predetermined value of 850 $kg.m^{-3}$, and varied from 841 to 863 $kg.m^{-3}$, i.e. the variation of this main exploitation and characteristic parameter of the panels was only 2.6% which justified the analysis of the influence of different types of non-wood lignocellulosic materials on the properties of the MDF panels produced.

A comparative analysis in a graphical form of the water absorption variation of MDF panels, produced at different content of the studied non-wood lignocellulosic materials, is presented on Figure 2.

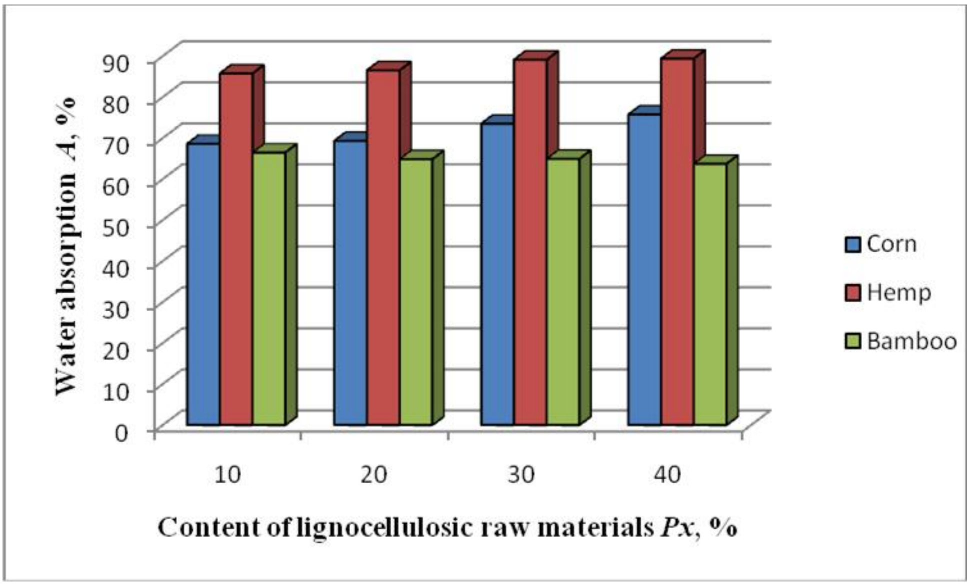

***Figure 2.** Variation of water absorption of MDF panels produced at different content of non-wood lignocellulosic materials*

Water absorption of the MDF panels deteriorated (increased) with the addition of maize and hemp stalk mass, whilst the addition of bamboo stalk mass resulted in improved values of the studied parameter. The deterioration of water absorption of the panels was determined when the content of maize stalk mass and hemp stalk mass exceeded 20% and 10%, respectively.

The lowest water absorption (63.7%) was determined for MDF panels with 40% content of bamboo stalk mass. The highest values of this indicator were observed for MDF panels produced with 40% content of hemp stalk mass, where 89.1% water absorption was reported. Comparative analysis showed that the best (lowest) values of water absorption at equal percentage content of non-wood lignocellulosic raw materials were determined for MDF panels produced with bamboo stalks, and the worst values were determined for the panels produced with industrial hemp stalks. Water absorption of MDF produced with maize stalks is similar to the one of MDF with bamboo stalks.

A comparative analysis in a graphical form of the swelling in thickness of MDF panels produced at different content of the studied non-wood lignocellulosic materials is presented in Figure 3.

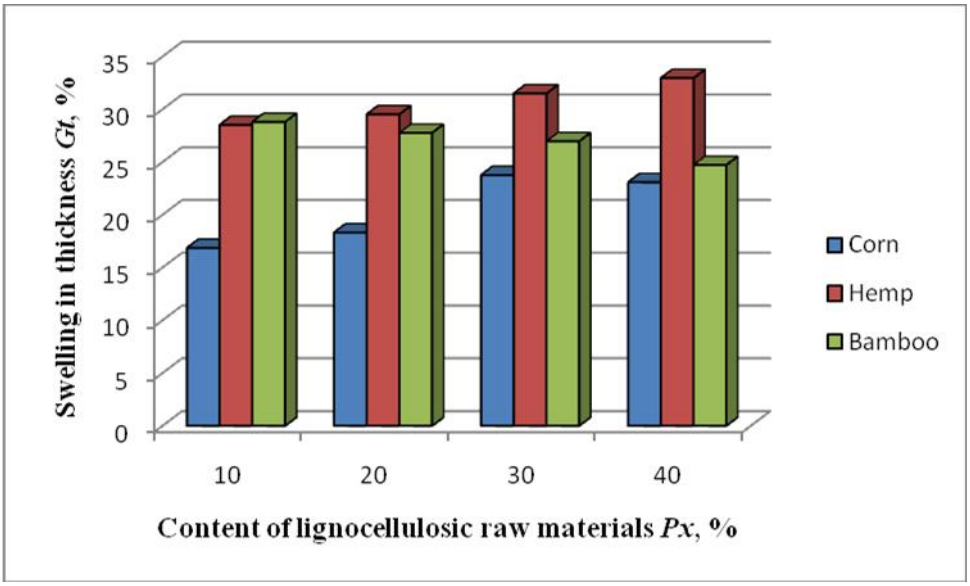

Figure 3. *Variation of swelling in thickness of MDF panels produced at different content of non-wood lignocellulosic materials*

The addition of all studied types of non-wood lignocellulosic raw materials resulted in deterioration (increase) of swelling in thickness.

Regarding swelling in thickness, only the panels produced with 10% content of maize stalk mass met the standard requirements for application in humid environment. The panels produced with 20% content of maize stalk mass exceeded the standard requirement (EN 622-5) insignificantly, with a variation within the statistical error. All panels produced with participation of maize stalk mass met the requirements for application in dry conditions.

The most significant deterioration of swelling in thickness of MDF panels produced with industrial hemp stalk mass was determined when the content of non-wood lignocellulosic raw material was increased from 30 to 40%. The panels produced with industrial hemp stalks met only the requirements for use in dry conditions. The addition of bamboo stalk mass resulted in deteriorated swelling in thickness at 10% content of non-wood raw material, followed by constant levels of the values with a slight decrease.

The best values of swelling in thickness were determined for MDF panels produced with participation of maize stalks; the highest value of swelling in thickness was reported when using industrial hemp stalk mass.

A comparative analysis in a graphical form of the bending strength of MDF panels produced at different content of the studied non-wood lignocellulosic materials is presented in Figure 4.

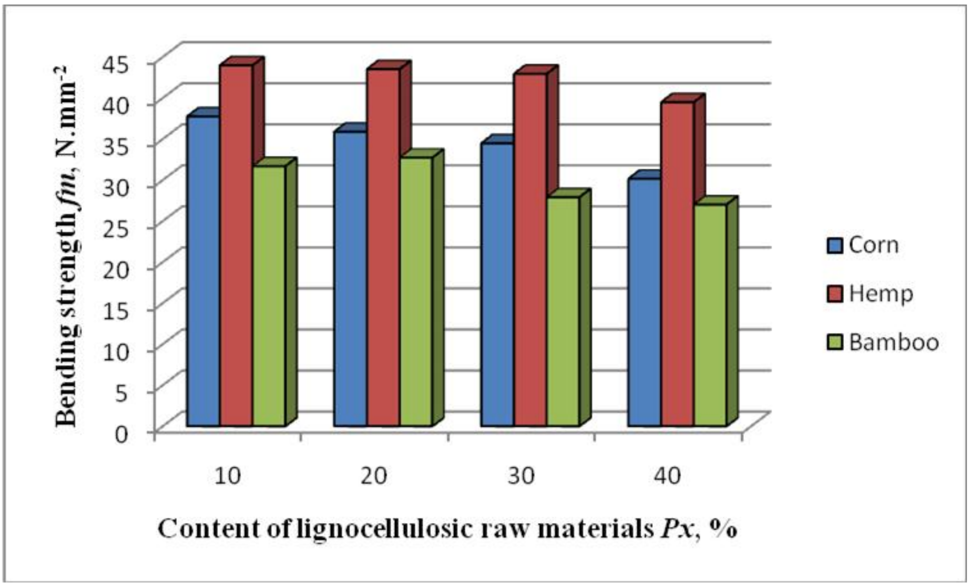

Figure 4. *Variation of bending strength of MDF panels produced at different content of non-wood lignocellulosic materials*

The highest bending strength values of the studied lignocellulosic raw materials were determined for MDF panels produced with participation of industrial hemp stalk mass, followed by the panels produced with maize stalk mass. The worst values of this indicator were determined for MDF produced with bamboo stalk mass.

Regarding the bending strength, the panels produced with maize stalk and hemp stalk mass up to 40% met the stringent requirements, i.e. for load-bearing applications in humid environment. However, it should be noted that the inclusion of more than 20% non-wood lignocellulosic mass resulted in significant decrease of the bending strength. The panels produced with up to 20% non-wood mass met the standard requirements for load-bearing applications and use in dry conditions.

4. CONCLUSIONS

As a result of the present study, it was determined that, in general, the studied non-wood lignocellulosic raw materials, if not treated in advance, lower the physical and mechanical properties of the panels. However, this type of raw material can successfully be incorporated in the composition of MDF panels as a partial substitute of wood. Regarding the swelling in thickness all MDF panels produced with maize stalk mass met the standard requirements for general application and use in dry conditions. MDF panels produced with industrial hemp stalks met the standard requirements at up to 20% content of non-wood lignocellulosic raw material. With regard to the panels produced with bamboo stalk mass the content of lignocellulosic raw material should be at least 20%.

All produced MDF panels met the bending strength requirements for general application and use in dry conditions. MDF produced with a content of maize stalk stem mass up to 40% met the most stringent requirements for load-bearing applications and use in humid environment; these requirements are met also by the MDF panels produced with industrial hemp stalk mass up to 20%.

In the comparative analysis of the physical and mechanical properties of MDF produced with maize, industrial hemp and bamboo stalk mass, it was determined that maize stalks are the most suitable raw material, followed by the hemp stalks. Maize crops have a relatively larger distribution; the main disadvantage is the relatively low refining yield. Regarding the panels produced with bamboo stalk mass, a significant deterioration of panel strength properties was observed, mainly due to the chemical composition of bamboo stalks. Despite these drawbacks, the use of all three studied non-wood raw materials in the composition of MDF panels can be recommended, even without initial chemical treatment of the lignocellulosic raw materials, as a partial substitute of wood. However, the share of this type non-wood raw material should not exceed 20%.

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