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ARAŞTIRMA MAKALESİ RESEARCH PAPER

Utilization of Mass of Industrial Hemp in the Production of Medium-density Fibreboards (MDF)

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Abstract: In the near past, industrial hemp (*Cannabis sativa* L. subsp. *sativa*) found main application in the production of ropes and fabrics. At the present moment, this crop finds increasingly big application for pharmaceutical purposes and in the cosmetics industry. As a result of which not only hurds, but whole stalks remain as waste from this production. On the other hand, MDF, which on a world scale are the second production of wood-based boards in terms of volume after that of veneer plywood, allow at least partial inclusion of non-woody lignocellulosic raw materials in their composition. That is why, in this paper, an investigation about the possibility for inclusion of mass of hemp stalks in the MDF composition is presented.

Under laboratory conditions, previously washed hemp stalks were defibred. The defibration was performed in a laboratory crusher defibrator for 2 min. Under laboratory conditions, MDF with participation of mass of hemp stalks form 0% to 100% in the MDF composition were produced. The content of mass of hemp stalks was increased by a step of 10%. The boards were produced at a temperature of hot pressing of 185 °C, with 10% participation of urea-formaldehyde resin (UFR) and have a density of 850 kg/m^3.

The effect of the content of mass of hemp stalks on the physicomechanical indicators of MDF was established. Regression equations for this effect on the individual physicomechanical indicators were also derived. It has been established in case of increase of what share in the composition of boards, most significant deterioration of the MDF indicators is observed. On this basis, a recommendation for the maximum justified content of mass of hemp stalks in the MDF composition was derived.

Keywords: MDF, Non-woody lignocellulosic raw material, Stalks of industrial hemp.

INTRODUCTION

Industrial hemp (*Cannabis sativa* L.) has many different applications, mainly in the production of paper, fabrics, biodegradable plastics, building materials, healthy food, fuels and another approximately 50,000 types of applications besides industry, in medicine and potentially in almost any other sphere.

Hemp is an annual plant that reaches 5 m in height and 6 to 60 mm stalk thickness for a period of growth of about 3 months depending on the plantation density (Mohanty et al, 2000).

This is one of the fastest growing biomasses known to man and one of the plant crops most early known and home-grown by man. Hemp does not require pesticides for its cultivation, does not lead to erosion of soil, just the contrary, it aerates it by producing oxygen (https://www.konop.bg).

Hemp stalk consists of lignified heartwood with wide pith, covered by a cambial layer, bast, bark and epidermis (Fig. 1).

Bast represents about 1/4 of the stalk and plays a main role for the tensile strength and, respectively, bending strength of the stalk. Bast is covered by epidermis covered with great number of cuticles that protect the plant from parasites by means of the strong resins they secrete. Xylem (so called lignified part) of the stalk represents about 3/4 of the volume and plays a main role for the plant firmness.

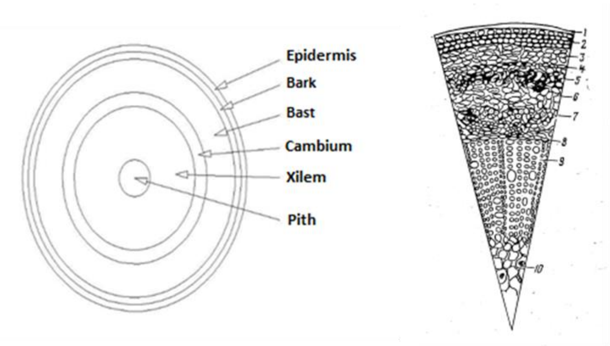

Figure 1. Structure of hemp stalk. (1- epidermis; 2 - collenchyma; 3 – cortical parenchyma; 4 – endodermis; 5 – primary bast fibres; 6 – bast parenchyma; 7 – vascular tissue; 8 – cambium; 9 – wood; 10 – pith)

There are considerable differences between the chemical composition of the xylem and the bast of the hemp stalk. The bast fibres have cellulose content of about 60-70%, hemicelluloses – 15-20%, lignin – 2-4%, pectins – 2-4%, fats and waxes – 1-2%. Xylem has rather content analogous to broad-leaved tree species: cellulose about 40%, hemicelluloses about 25%, lignin about 20% and extractives – 4% (Garcia-Jaldon et al., 1998). This difference determines also the serious difference in the strength of bast fibres and those of xylem, that is why whole stalks comprising both types of fibres were used for the investigation.

In the past, hemp was mainly grown to use the bark fibres for ropes, paper and textile, but nowadays these productions are supplemented by the extraction of high-quality seed oil and resins irreplaceable for medicine, the plant value being increased many times in this way and its cultivation becoming low-risk and promising business. In most of those productions, waste are exactly hemp stalks that, in the countries developing this branch, are abundant and acquire industrial significance. In older references, directions are given for the use of hemp as additive to wood raw material at most up to 30% of the total mass, but in recent investigations results meeting some basic standards at hemp content of 60% of the raw material's total mass were achieved (Radosavljevic et al., 2008). Characteristic of hemp, as well as of wheat lignocellulosic waste is the need for treatment with weak solution of alkali (NaOH 5-8%) and 1 to 3% of oligomeric siloxane in alcohol solution because they separate hemicelluloses, lignin and waxes from the fibres and thus assist the adhesion at a later stage, and, hence, increase the strength and performance characteristics (Kabir et al., 2012).

It should be emphasized that there is a considerable amount of investigations about utilization of hemp stalks in particleboards (PB) composition (Mahieu et al., 2015; Shöpper et al., 2008; Selinger et al., 2015), while investigations about their utilization in MDF composition are considerably fewer (Fajrin, et. al. 2018).

MATERIAL and METHODS

For the purposes of the investigation, MDF with set thickness of 8 mm and density of 850 kg/m^3 were produced under laboratory conditions. Urea-formaldehyde resin at content of 10% relative to the oven-dry mass was used as binding agent.

The wood-fibre mass that was used to produce the boards was produced in the fibreboards (FB) factory of VELDE Bulgaria AD – the town of Troyan. It is composed of wood of Turkey oak and beech to the ratio of approximately 2:1 and has water content of 10%.

The hemp mass was produced in the Pressing Laboratory of the Chair of Mechanical Wood Technology at the University of Forestry. The hemp stalks with diameter of 6 to 32 mm were previously cut to a length of 200 mm and were immersed in water for 5 days at room temperature. Defibration was performed with laboratory defibrator in amounts of 100 to 150 g with addition of additional 200 ml of water and cycle duration of 150 s, whereupon they were dried at a temperature of 100 °C to water content of 6%. The fibres obtained in this way were sifted through a sieve with mesh of 2x2 mm and are up to 5 mm long.

Urea-formaldehyde resin produced by KASTAMONU Bulgaria AD was used as binding agent. The resin is with initial concentration of 68% and working concentration of 55%.

For the purpose of the investigation, 11 boards with various share of hemp mass within the range of 0 to 100%, at a step of 10%, were produced.

Pressing was performed at a platen temperature of 185 ± 5 °C and duration of 1 min/mm, in three stages, at specific pressure as follows: 1st stage – 2.6 MPa; 2nd stage – 1.3 MPa; 3rd stage – 0.6 MPa. The duration of the individual stages is the following: 1st stage – 12.5% of the complete cycle; 2nd stage – 37.5% of the cycle; 3rd stage – 50% of the pressing cycle.

Determination of the performance indicators of the boards was performed in conformity with the valid European norms EN 310; EN 316; EN 317; EN 323.

The results for the performance indicators of MDF, depending on the content of mass of hemp stalks, were processed after the methods of variation statistics and regression analysis, with approximation functions being derived for the examined relationships. The coefficient of determination was used as a measure for definiteness.

RESULTS and DISCUSSION

The summarized results for the performance indicators of MDF, depending on the content of mass of hemp stalks, are presented in Table 1.

Table 1. Performance indicators of MDF, depending on the content of mass of hemp stalks.

No	Content of mass of hemp stalks *Px*, %	Density *ρ*, kg/m^3	Water absorption *A*, %	Swelling in thickness *Gt*, %	Bending strength *fm*, N/mm^2
1	0	848	81.44	28.53	44.02
2	10	854	85.78	29.53	43.99
3	20	845	86.54	31.50	43.52
4	30	858	89.13	32.96	42.96
5	40	846	89.40	36.03	39.49
6	50	850	95.61	40.41	34.19
7	60	844	94.54	40.44	34.03
8	70	860	96.70	41.18	34.97
9	80	859	100.2	41.47	31.21
10	90	850	102.2	41.04	22.32
11	100	846	119.2	50.43	23.30

In graphic form, the variation of the water absorption of MDF, depending on the content of mass of hemp stalks, is presented in Fig. 2.

The relationship between the water absorption and the content of mass of hemp stalks is described with regression equation of the type:

$$\widehat{A} = 84.18 + 0.026.P_x + 0.003.P_x^2, \quad (1)$$

where $\widehat{A}$ is the predicted value for water absorption of the boards, %;

Px – the content of mass of hemp stalks, %.

Equation (1) is characterized with coefficient of determination, R^2, of 0.95.

From the data presented is seen that with addition of mass of hemp stalks in the MDF composition, the water absorption of the boards increases, i.e. deteriorates. Under the conditions of the experiment, the water absorption varies from 81.44 to 119.2%. Lowest is the water absorption of the board obtained from 100% wood raw material, and highest – in that obtained from 100% hemp stalks. Deterioration of the indicator is by 37.76%. Significant deterioration of the water absorption is observed already with the addition of the first 10% of mass of hemp stalks – by 4.34%. Increase of water absorption is also recorded in case of further increase of the content of mass of hemp stalks, with the deterioration being more significant in case of increase of its content from 20 to 30% (by 2.59%), from 40 to 50% (by 6.21%), from 70 to 80% (by 3.50%). Most significant deterioration of this indicator is observed in case of increase of the content of mass of hemp stalks from 90 to 100%.

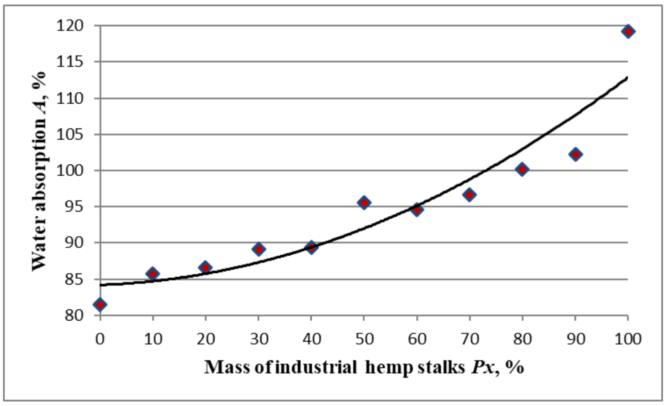

Figure 2. Variation of the water absorption of FB, depending on the content of mass of hemp stalks.

The dependence of the swelling in thickness of MDF on the content of mass of hemp stalks in their composition is presented in Fig. 3.

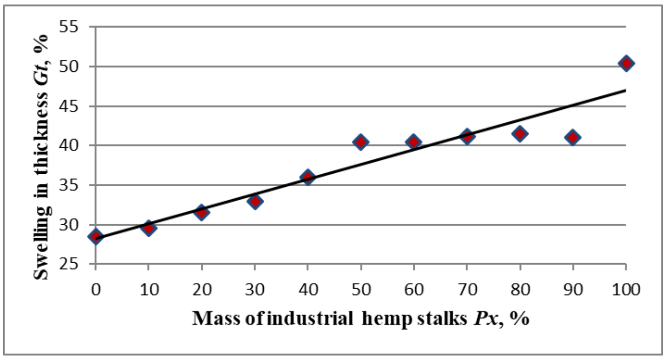

Figure 3. Variation of the swelling in thickness of FB, depending on the content of mass of hemp stalks.

The relationship between the content of mass of hemp stalks and the swelling in thickness of MDF is of the type:

$$\widehat{Gt} = 28.22 + 0.19.P_x, \quad (2)$$

where $\widehat{Gt}$ is the predicted value for the swelling in thickness of boards, %;

Px – the content of mass of hemp stalks, %.

The equation is characterized with coefficient of determination R^2 = 0.86.

Under the conditions of the experiment, the swelling in thickness of MDF varies from 28.53 to 50.43%, i.e. here also we observe deterioration of the indicator with increase of the content of mass of hemp stalks in the composition of boards, with this deterioration being by whole 21.9%. Lowest is the swelling in thickness of FB entirely composed of wood raw material, and highest in those composed entirely of mass of hemp stalks. Most significant deterioration of the indicator is observed in case of increase of the content of mass of hemp stalks from 90 to 100%, where the increase is by 9.39%. More significant deterioration of the indicator is also observed in case of increase of the content of mass of hemp stalks from 30 to 40%, as well as in case of increase of the content of mass of hemp stalks from 40 to 50% (by 4.38%).

In graphic form, the variation of the bending strength of MDF, depending on the content of mass of hemp stalks in their composition, is presented in Fig. 4.

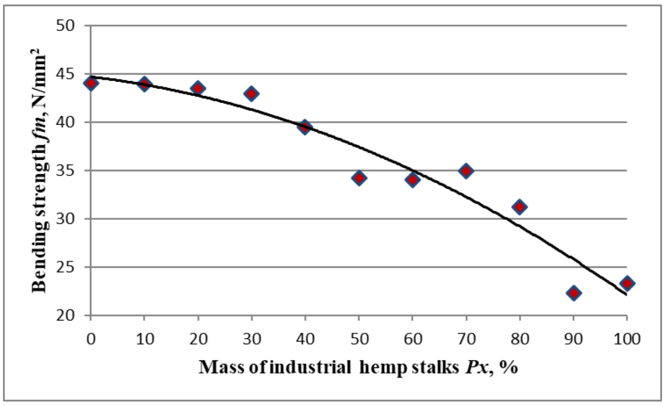

Figure 4. Variation of the bending strength of FB, depending on the content of mass of hemp stalks

The regression equation in the case of this indicator is:

$$\widehat{fm} = 44.70 - 0.065.P_x - 0.002.P_x^2 , \qquad (3)$$

where $\widehat{fm}$ is the predicted value for the bending strength of boards, N/mm^2;

Px – the content of mass of hemp stalks, %.

The equation is characterized with coefficient of determination $R^2 = 0.96$.

As a whole, with increase of the content of mass of hemp stalks, the bending strength of the obtained MDF deteriorates.

Under the conditions of the investigation, the bending strength of the boards varies from 44.02 to 23.30 N/mm^2. The total deterioration is by 20.72 N/mm^2. Most significant deterioration of the indicator is recorded in case of increase of the content of mass of hemp stalks from 80 to 90% (by 8.89 N/mm^2), from 70 to 80% (by 3.76 N/mm^2) and from 30 to 40% (by 3.47 N/mm^2).

In spite of the deterioration of the indicator as a whole, the boards with content of up to 80% mass of hemp stalks meet the requirements for bending strength for boards of general purpose, for use in dry environment (23 N/mm^2) and for use in humid environment (27 N/mm^2 for type MDF.LA). The boards with content of up to 80% mass of hemp stalks also meet the requirements for bending strength to boards for bearing structures, used in humid environment (34 N/mm^2 for type MDF.HLS).

CONCLUSIONS

As a result of the investigation performed about the effect of participation of mass of hemp stalks on the performance indicators of MDF, the following conclusions may be drawn and the following recommendations may be made:

• The industrial hemp stalks may be successfully used as a substitute for the wood raw material in the MDF composition;

• It is recommended that the investigations about the utilization of hemp stalks as part of the MDF composition are continued by looking for possibilities for improvement of the hydrophobic properties of the boards.

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REFERENCES

EN 310. (1993). Wood-based panels-Determination of modulus of elasticity in bending and of bending strength

EN 316. (2009). Wood fibreboards-Definition, classification and symbols.

EN 317. (1998). Particleboards and fibreboards. Determination of swelling in thickness after immersion in water.

EN 323. (1993). Wood-based panels-Determination of density.

EN 622-5. (2010). Fibreboards-Specifications-Part 5: Requirements for dry process boards (MDF).

Fajrin, J. & Herlina Sari, N. (2018). tensile properties of lignocellulosic composites: A comparison analysis between natural fibre composites (NFCs) and medium density fiber (MDF). *Jurnal Spektran, **6***, 1, 111–116. e-ISSN: 2302-2590.

Garcia-Jaldon, C., Dupeyre, D. & Vignon, M.R. (1998). Fibres from semi-retted hemp bundles by steam explosion treatment. *Biomass and Bioenergy, **14*** (3), 251-260.

Kabir, M.M., Wang, H. & Lau, K.T. (2012). Mechanical properties of chemically-treated hemp fibre reinforced sandwich composites. *Composites: Part B, **43***(2), 159-169.

Mahieu, A., Lenormand, H., Leblanc, N. & Vive, A. (2015). 100% Bio-based particleboards based on new agricultural wastes. *First International Conference on Bio-based Building Materials. Clermont-Ferrand*, France June 22nd-24th 2015, 1-6pp.

Mohanty, A.K., Misra, M. & Drzal, L.T. (2002). Sustainable bio-composites from renewable resources: Opportunities and challenges in the green materials world. *Journal of Polymers and the Environment, **10***, 19-26.

Radosavljevic, Lj., Pecenka, R. & Fürll, Ch. (2008). Natural binders for fibreboard made of hemp.

International Conference on Flax and Other Bast Plants, 70-74pp. ISBN 978-0-9809664-0-4.

Schöpper, Ch. & Alireza Kharazipour, A. (2009). Production of innovative hemp based three-layered particleboards with reduced raw densities and low formaldehyde emissions. *International Journal of Materials and Product Technology,* 46-59. Doi: 10.1504/IJMPT.2009.027842

Selinger, J. & Wimmer, R. (2015). A novel low-density sandwich panel made from hemp. *Wood 2015: Innovations in wood materials and processes Brno*, Czech Republic, May 2015, pp. 93-94.

Thakur, V.K. (2014). *Green composites from natural resources*. Taylor and Francis Group. ISBN 13: 978-1-4665-7070-2.

Thoemen, H., Irle, M. & Semek, M. (2010). Wood-Based panels an introduction for specialists. Brunel University Press. ISBN 978-1-902316-82-6.

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