

## PROPERTIES OF PARTICLEBOARDS WITH THE PARTICIPATION OF HEMP AND VINE PARTICLES IN THE CORE LAYER – PART I: EFFECT OF THE COMPOSITION

Rosen Grigorov, Viktor Savov, Slavcho Alexandrov

University of Forestry, Sofia, Bulgaria

e-mail: rosenigorov@ltu.bg; victor\_savov@ltu.bg; .aleksandroff@icloud.com

### ABSTRACT

Increasing deforestation worldwide, on the one hand, and the increased production of wood-based panels, on the other hand, lead to the need for alternative lignocellulosic raw materials. In this context, it should be said that significant amounts of lignocellulosic biomass remain annually from agricultural production, and unfortunately, that biomass is generally burned. However, individual types of lignocellulosic non-wood raw materials can hardly cover the needs of wood-based panel manufacturers, which necessitates their combination.

For the aim of the study, particleboards with a core layer of vine and hemp particles were produced. The contents of vine and hemp particles varied from 0 to 100% in steps 20%. A control panel composed only of wooden raw material was also fabricated, and the face layers of the panels were from hardwood particles.

As a result of the study, it was found that the variation in the composition of the core layer does not affect the waterproof properties of the panels. In contrast, with the increased content of hemp particles, the mechanical properties of particleboards improved significantly.

**Key words:** particleboards, non-wood lignocellulosic raw material, vine particles, hemp particles.

### INTRODUCTION

Particleboard production is significant worldwide, with an annual volume of over 100 million m<sup>3</sup> (FAO). The output of this type of wood-based panels is dominant in the EU, and particleboards are used as the primary construction material in furniture production (Jivkov, V. and Elenska-Valchanova, D. 2019; Jivkov, V. and Petrova, B. 2020).

The primary raw material for particleboards is the small-sized and low-quality round wood obtained during logging and the waste from wood processing, such as clippings, lids, sawdust, veneer clippings, chips, shavings, etc. (Mihajlova, J. 2020).

The deepening shortage of wooden raw materials necessitates searching for alternative lignocellulosic sources (Sackey, E. M. et al. 2008; Mohanty, A. K. et al. 2018; Hubbe,

M. A. et al. 2018). Various lignocellulosic residues from annual and perennial crops can be used in particleboard production (Pallesen, B. E. et al. 1996; Auriga, R. et al. 2021). These residues have a chemical composition close to the wood, making them suitable for use in this production (Hubbe, M. A. et al. 2018). Some of the possible raw materials that can be used are grape vines and hemp stems (Auriga, R. et al. 2020; Ferrandez-Villena M et al. 2020; Kallakas, H.). Traditionally, on a global scale, viticulture is widely practised, which is a prerequisite for the presence of large quantities of vine sticks. Industrial hemp cultivation is also traditionally advocated and has been growing in recent years (FAO), which means that the amount of hemp stalk waste will increase.

There are studies where vine and hemp particles have been successfully used as raw

materials for particleboards. These raw materials are mainly applied in the panels' core layer (Réh, R. and Vrtielka, J. 2013; Grigоров, R. et al. 2020; Zvirgzds, K. et al. 2022).

Due to the large capacities of contemporary particleboard production plants, fabrication of panels with only one lignocellulosic non-wood raw material would not be easy.

This study aimed to determine the influence of the composition of the interlayer on the performance of three-layer particleboards with different contents of vine and hemp particles.

## MATERIALS AND METHODS

In this study, seven types of three-layered particleboards were produced, Table 1.

Table 1: Experimental plan

Panel Type	Content of wood particles in the face layers, %	Content of hemp particles in the core layer, %	Content of vine particles in the core layer, %	Content of wood particles in the core layer, %
A	100	0	100	0
B	100	20	80	0
C	100	40	60	0
D	100	60	40	0
E	100	80	20	0
F	100	100	0	0
REF	100	0	0	100

The ratio of face to the core layer was 40:60. For the face layers of the panels, hardwood particles from Beech (*Fagus Silvatica*, L) and Turkish Oak (*Quercus Cerris*, L) were used. This type of raw material for the faces was chosen given the higher compression ratio of the face layers and the possibility of utilizing small-sized hardwood. The fractional composition of the particles for face layers was determined on a laboratory sieve analyzer and was as follows: fraction 2.0÷1.0 mm – 39.60%, fraction 1.0÷0.5 mm – 36.00%, fraction 0.5÷0.2 mm – 19.50%; 0.2÷0.1 mm – 3.30%, fraction below 0.1 mm – 1.60%. The moisture content of particles for face layers was 11.3%.

For the core layer of the particleboards, vine and hemp particles were used in substitution at 20%. A control panel with wood particles in the core layer was also produced, see Table 1. The raw materials were chipped on a hammer mill FCh-500, manufactured by "Sila", Bulgaria.

The moisture content of particles for the core layer was as follows: vine particles –

10.8%; hemp particles – 10.6%; and wood particles 11.1%.

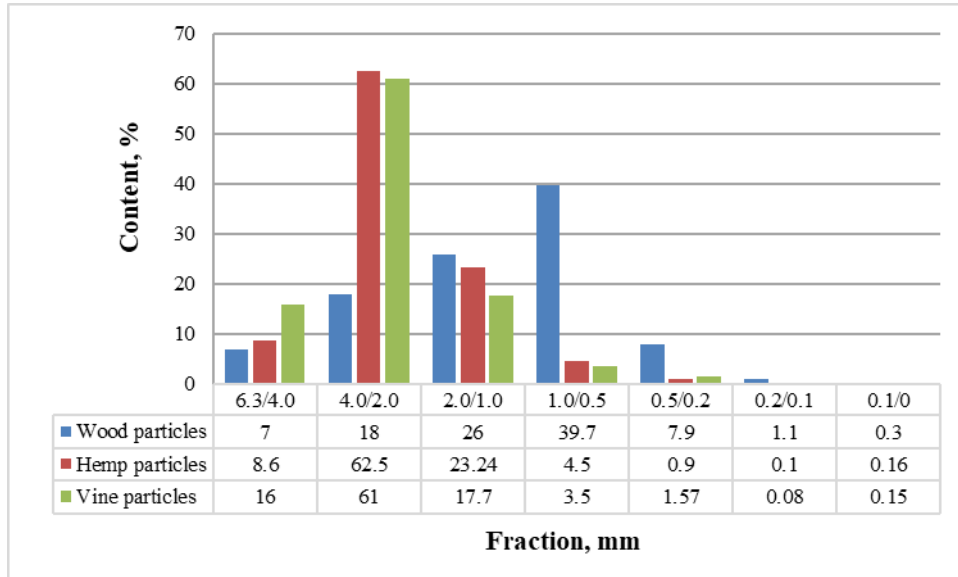
As a binder, urea-formaldehyde (UF) resin was used with a content of 10% relative to the dry wood particles. The UF resin had a molar ratio of 1.08 and a dry solids content of 50%. Ammonium sulphate of 1% based on the dry resin was used as a hardener. As a waterproof substance, a wax (paraffin) emulsion was used at the content of 1% based on the dry particles.

The panels had a set density of 620 kg.m<sup>-3</sup>, a set thickness of 16 mm, a width of 450 mm and a length of 450 mm. The particleboards were produced at 175°C hot-pressing temperature and a press factor of 30 s.mm<sup>-1</sup>. A three-stage hot-pressing regime was used: pressure during the first stage of 2.5 MPa and a press time of 1 min; pressure during the second stage of 1.2 MPa and press time of 4 min; pressure during the third stage of 0.6 MPa and a press time of 3 min. The hot-pressing was performed on a single-opening laboratory press type PMS ST 100, Italy. The hot pressing regime is by the recommended regimes from similar studies with

a similar moisture content of the raw materials (Mihajlova, J. et al. 2015; Mihajlova, J. 2020; Valyova, M. and Koynov, D. 2020). The properties of particleboards were determined by the EN standards (EN 310, EN 317, EN 319, EN 323). Eight test samples were tested for each property of the panels.

**RESULTS AND DISCUSSION**

The fractional composition of the particles used for the core layer of the panels is presented in Figure 1.



**Figure 1: Fractional composition of different lignocellulosic particles**

The results for the fractional composition of the different particles show that, in practice, the vine and hemp particles have very similar fractional compositions. Their main fraction is 4.0/2.0. While for the wood particles intended for the core layer of the panels, the main fraction is 1.0/2.0. That shows that the non-woody lignocellulosic particles have a longer length and hence a larger active contact area than the wood particles. The importance of particle sizes for the properties of the particleboards is confirmed by the studies of Sackey, E. M. et al. 2008, as well as Zvirgzds, K. et al. 2022.

The bulk densities of the particles used for the core layer are as follows: wood particles – 125 kg.m<sup>-3</sup>; vine particles – 158 kg.m<sup>-3</sup>; hemp particles – 95 kg.m<sup>-3</sup>. That shows that using hemp particles will lead to the highest compression ratio. The vine particles have the highest bulk density and,

therefore, the lowest compression ratio. When using vine particles as raw material, it is recommended to increase the density of particleboards and, by that to be increased the compression ratio. Lighter (with lower density) particleboards can be fabricated when hemp particles are used. In that case, the compression ratio will be sufficient and hence physical and mechanical properties of the panels will be satisfactory.

The moisture content, with the main statistics, of the laboratory particleboards, is presented in Table 2.

The results show that particleboards were acclimatized and had reached exploitation moisture content (4 to 9%), according to EN 322.

The data on the density, with the main statistics, of the laboratory particleboards, are presented in Table 3.

Table 2: Moisture content, with main statistics, of laboratory particleboards

Panel Type	Content of hemp particles in the core layer, %	Content of vine particles in the core layer, %	Content of wood particles in the core layer, %	Moisture content (mean value) $H$ , %	Standard deviation $S_y$ , %	Standard error $m_y$ , %	Probability $P_y$ , %
A	0	100	0	6.05	0.72	0.12	1.97
B	20	80	0	6.14	0.43	0.07	1.14
C	40	60	0	6.16	0.69	0.11	1.82
D	60	40	0	6.77	0.31	0.05	0.67
E	80	20	0	6.28	0.62	0.10	1.58
F	100	0	0	6.62	0.16	0.02	0.37
REF	0	0	100	6.50	0.24	0.04	0.58

Table 3: Density, with main statistics, of laboratory particleboards

Panel Type	Content of hemp particles in the core layer, %	Content of vine particles in the core layer, %	Content of wood particles in the core layer, %	Density (mean value) $\rho$ , kg.m <sup>-3</sup>	Standard deviation $S_y$ , kg.m <sup>-3</sup>	Standard error $m_y$ , kg.m <sup>-3</sup>	Probability $P_y$ , %
A	0	100	0	619	31.96	11.30	1.83
B	20	80	0	630	25.07	8.86	1.41
C	40	60	0	641	20.04	7.08	1.11
D	60	40	0	634	37.86	13.39	2.11
E	80	20	0	625	31.81	11.25	1.80
F	100	0	0	624	47.60	16.83	2.70
REF	0	0	100	638	19.80	7.00	1.10

The density of particleboards varies from 619 to 641 kg.m<sup>-3</sup>. That is, the maximum deviation in this main property is 3.6%. The density is very close to set one of 620 kg.m<sup>-3</sup>. The conducted ANOVA, Table

4, shows that the composition of the panels does not affect their density. That is due to the production method used, namely the application of restraint metal bars during hot-pressing.

Table 4: ANOVA for the density of particleboards

Source of Variation	SS	df	MS	F	p-Value	F <sub>crit</sub>
Content of hemp particles	1569.90	5	313.98	0.288	0.917	2.427
Content of vine particles	2234.90	5	446.98	0.411	0.838	2.427
Content of wood particles	568.36	1	568.36	0.523	0.473	4.062
Error	47819.68	44	1086.81	–	–	–
Total	52192.84	55	–	–	–	–

The water absorption of particleboards with different compositions of the core layer is presented in Figure 2.

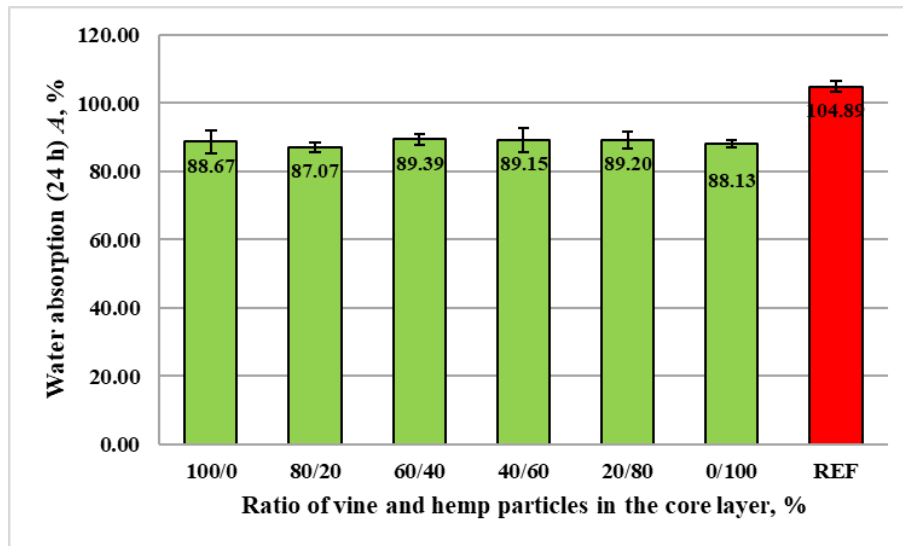


Figure 2: Water absorption (24 h) of particleboards with different compositions of the core layer

When analyzing the data on water absorption of the particleboards with the participation of vine and hemp particles in the core layer, it was found that the type of non-wood lignocellulosic raw material does not affect that property. That is confirmed by the conducted t-tests, and the corresponding data for *p*-values are as follows: particleboard types A/B – *p* = 0.542; B/C – *p* = 0.175; C/D – *p* = 0.932; D/E – *p* = 0.752; E/F – *p* = 0.695. The panels fabricated with lignocellulosic raw material have a lower water absorption than the particleboards fabricated only with wood particles. The t-test shows a statistically sig-

nificant difference in the values of this property between particleboards Type F and REF (*p*-value is  $1.089 \cdot 10^{-5}$ ). An explanation of that can be sought with the lower bulk density of the hemp particles and hence the greater compression ratio when using this material (Kallakas, H. et al. 2018). When vine particles are used, a greater amount of waterproof substances characteristic of this material are included in the composition of the panels (Ferrandez-Villena M. et al. 2020; Auriga, R. et al. 2022).

The thickness swelling of the panels is presented in Figure 3.

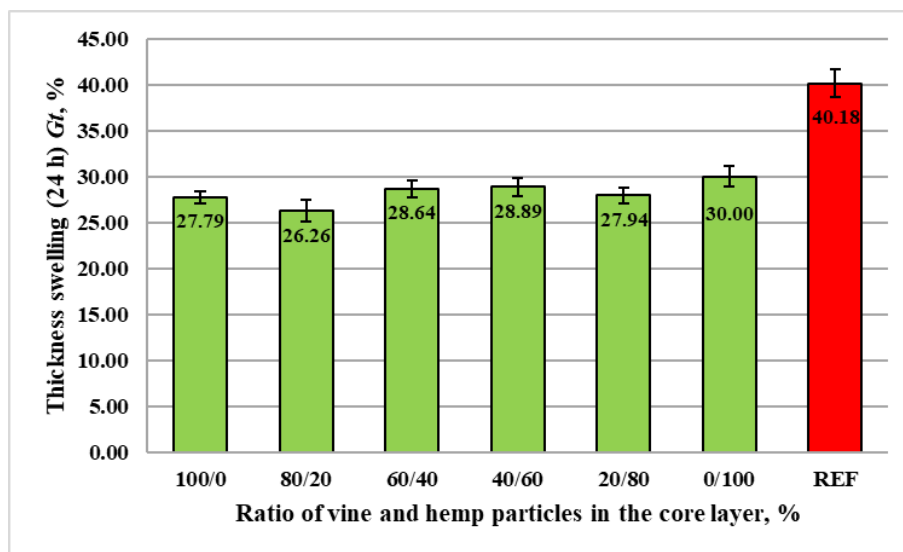


Figure 3: Thickness swelling (24 h) of particleboards with different compositions of the core layer

From the data, it is clear that the thickness swelling of the panels is in the range of 26% to 30%, and there is no clear tendency for the effect of the hemp and vine particles. That is also confirmed by the conducted t-tests, where it was found that there is no statistically significant difference between the values of this property in the panels with the participation of vine and hemp particles. The results of the t-tests are as follows: particleboard types A/B –  $p = 0.150$ ; B/C –  $p = 0.064$ ; C/D –  $p = 0.791$ ; D/E –  $p = 0.311$ ; E/F –  $p = 0.074$ . The thickness swelling of wood particleboards is 1.25 to 1.35 times higher

than that of hemp and vine particleboards. The t-test shows a statistically significant difference in the values of this property between particleboards Type F and REF ( $p$ -value is  $5.574 \cdot 10^{-5}$ ). An explanation of these results should be sought in the lower bulk density of the hemp particles and the higher content of waterproof substances in the chemical composition of the vine particles (Kallakas, H. et al. 2018; Ferrandez-Villena M. et al. 2020; Auriga, R. et al. 2022).

The modulus of elasticity of particleboards with different compositions of the core layer is presented in Figure 4.

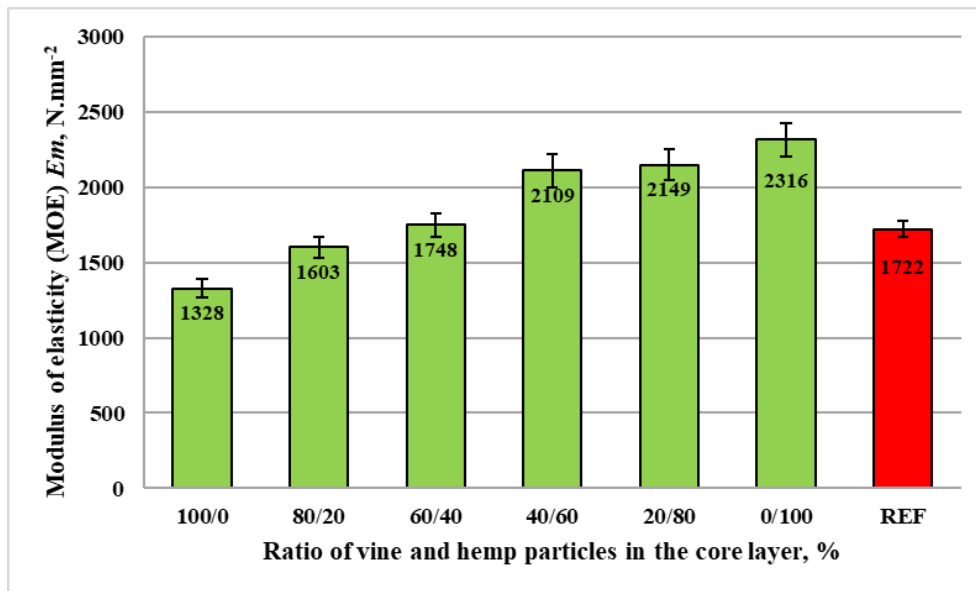


Figure 4: Modulus of elasticity (MOE) of particleboards with different compositions of the core layer

From the results, it is clear that the MOE increases with the increase in the participation of hemp particles in the core layer composition. Its lowest value is  $1328 \text{ N.mm}^{-2}$  for 0% hemp content, and the highest MOE value is  $2316 \text{ N.mm}^{-2}$  at 100% content of hemp particles, where we observe an increase of 74%. That is because the bulk density of hemp is much lower than that of vine particles. Because of that, to achieve the set density, more hemp particles are used, which leads to the insertion of more lignocellulosic fibres into the composition of the panels.

Panels with more than 20% hemp particles in the core layer meet the requirements of the standard for Type P2 particleboards for furniture production (EN 312). The modulus of elasticity for this type of panel should be at least  $1600 \text{ N.mm}^{-2}$ .

Increasing the participation of hemp particles by more than 40% in the core layer composition exceeds the particleboards' modulus of elasticity. And with 100% participation of hemp particles, the modulus of elasticity is 34.5% higher than that of the

panel fabricated with wood particles. Particleboards with hemp particles of 60 and 80% have a modulus of elasticity above  $1950 \text{ N.mm}^{-2}$ , which meets the requirements of EN-312 type P3 for non-load-bearing panels and use in humid conditions.

The panel with 100% participation of hemp particles in the core layer meets the requirements of EN-312 type P4 for load-bearing panels and use in dry conditions.

The data on the modulus of elasticity of the particleboards are consistent with those

reported by Réh, R. and Vrtielka, J. 2013. In their study, increasing the content of hemp particles to 80% in the core layer led to the fabrication of particleboards with a modulus of elasticity above  $3500 \text{ N.mm}^{-2}$ . On the other hand, the decrease in the modulus of elasticity of particleboards with increasing vine particle content was also reported by Auriga, R. et al. 2022 and Ferrandez-Villena M. et al. 2020.

The bending strength (MOR) of the laboratory panels is presented in Figure 5.

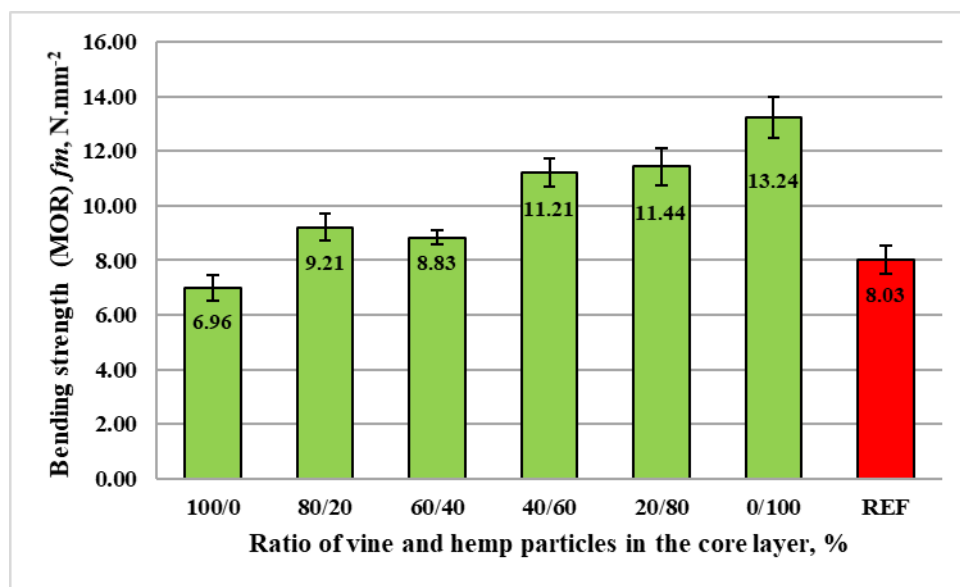


Figure 5: Bending strength (MOR) of particleboards with different compositions of the core layer

The data show that as the content of hemp particles in the core layer increases, the bending strength increases from  $7 \text{ N.mm}^{-2}$  at 0% hemp content to  $13.2 \text{ N.mm}^{-2}$  at 100% hemp participation. That improvement is 88.6%.

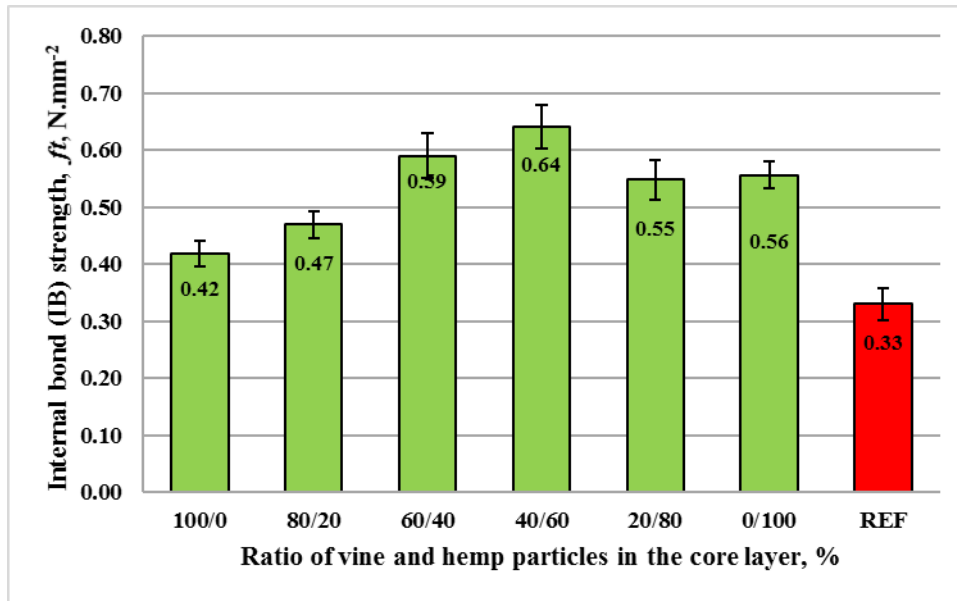
According to EN 312-2 standard furniture production requirements, panels' bending strength must be at least  $11 \text{ N.mm}^{-2}$ . That is fulfilled when the participation of hemp particles in the core layer is above 60%.

All particleboards, in which there is a participation of hemp particles, have a higher bending strength than the panel produced from wood particles. Only the particleboard

fabricated with a core layer of vine particles had a lower value of this property.

Again, the data on the improvement in bending strength with increasing hemp particle content is consistent with that obtained by Réh, R. and Vrtielka, J. 2013, who, at 80% hemp particle content in the core layer of panels, achieved a bending strength of more than  $18 \text{ N.mm}^{-2}$ . In general, due to their higher bulk density, an increase in the content of vine particles in the core layer of particleboards leads to a deterioration in the bending strength. This was also reported by Auriga, R. et al. 2022, and Ferrandez-Villena M. et al. 2020.

The data on the Internal bond (IB) strength of the particleboards are presented in Figure 6.



**Figure 6: Internal bond (IB) strength of particleboards with different compositions of the core layer**

From the data, it is visible that increasing the participation of hemp particles in an amount from 0 to 60% leads to an increase in the IB strength from 0.42 N.mm<sup>-2</sup> to 0.64 N.mm<sup>-2</sup>, which is an increase of 52%. All panels, except the one with 100% participation of vine particles, meet the requirements of EN-312 for use as load-bearing structures and use in humid conditions, type P5 particleboards (the IB strength must be at least 0.45 N.mm<sup>-2</sup>).

In this property, the positive influence of the low bulk density of the hemp particles is most firmly established, and conversely, the negative impact of the high bulk density of particles from vine sticks. The increased compression ratio with increased content of hemp particles leads to more contact areas and a corresponding increase in the IB strength of particleboards (Réh, R. and Vrtielka, J. 2013; Kallakas, H. et al. 2018). Conversely, a reduced compression ratio with increased vine particle content results in fewer contact areas and lower IB strength

(Auriga, R. et al. 2022; Ferrandez-Villena M. et al. 2020).

## CONCLUSIONS

As a result of the conducted research, it was found that the different content of hemp and vine particles does not affect the particleboards' waterproof properties (water absorption and thickness swelling). Increasing the participation of hemp particles in the core layer of the panels leads to a significant increase in the modulus of elasticity and bending strength.

Generally, increased content of hemp particles in the core layer, at the expense of reducing vine particles, leads to increased IB strength of the panels. This is mainly due to the low bulk density of hemp particles and therefore increased compression ratio when this raw material is used.

Particleboards with different percentages of hemp and vine particles have higher mechanical properties than panel fabricated entirely from wood particles.

In conclusion, while in terms of water-proof properties of particleboards, it was found that hemp and vine particles are equally suitable as raw material, in terms of mechanical properties, hemp particles showed significantly more excellent suitability as raw material.

### ACKNOWLEDGEMENTS

This research was supported by Project No. НИС-Б-1215/04.2022 "Properties and application of innovative biocomposite materials in furniture manufacturing" carried out at the University of Forestry, Sofia, Bulgaria.

**Conflicts of Interest:** The authors declare no conflict of interest.

### REFERENCES

- AURIGA, R., BORYSIUK, P., WARACKA, A., AURIGA, A. 2021. Susceptibility of drilling particleboard with share of hemp shives. *Biuletyn Informacyjny OB-RPPD* 3–4, pp. 115–121. DOI: 10.32086/biuletyn.2021.04.
- AURIGA, R., AURIGA, A., BORYSIUK, P., WILKOWSKI, J., FORMALCZYK, O., OCHMIAN, I. 2022. Lignocellulosic Biomass from Grapevines as Raw Material for Particleboard Production. *Polymers*, MDPI, 14, 2483. DOI: 10.3390/polym14122483.
- FERRANDEZ-VILLENA M, FERRANDEZ-GARCIA C.E., GARCIA-ORTUÑO T., FERRANDEZ-GARCIA A., FERRANDEZ-GARCIA M.T. 2020. Analysis of the Thermal Insulation and Fire-Resistance Capacity of Particleboards Made from Vine (*Vitis vinifera* L.) Prunings. *Polymers*, MDPI, 12(5):1147. DOI: 10.3390/polym12051147.
- GRIGOROV, R., MIHAJLOVA, J., SAVOV, V. 2020. Physical and Mechanical Properties of Combined Wood-Based Panels with Participation of Particles of Vine Sticks in Core Layer. *Innovation in Woodworking Industry and Engineering Design*, 17, pp. 42–52.
- HUBBE, M. A., PIZZI, A., ZHANK, H., HALIS, R. 2018. Critical Links Governing Performance of Self-binding and Natural Binders for Hot-pressed Reconstituted Lignocellulosic Board without Added Formaldehyde: A Review. *BioResources* 13(1), pp. 1–67. DOI: 10.15376/biores.13.1.Hubbe.
- JIVKOV, V., ELENSKA-VALCHANOVA, D. 2019. Mechanical Properties of Some Thin Furniture Structural Composite Materials. In *Proceedings of 30th International Conference on Wood Science and Technology*, pp. 86–94.
- JIVKOV, V., PETROVA, B. 2020. Challenges for furniture design with thin structural materials. *Proceedings of IFC2020*, pp. 113–123.
- KALLAKAS, H., NÄREP, M., NÄREP, A., POLTIMÄE, TR., KERS, J. 2018. Mechanical and physical properties of industrial hemp-based insulation materials. *Proceedings of the Estonian Academy of Sciences*, 67(2), pp. 183–192. DOI: 10.3176/proc.2018.2.10.
- MIHAJLOVA, J., ILIEV, B., POPOVSKA, V. J. 2015. Impact of Pressing Temperature on Physical and Mechanical Properties of Panels Made from Particles of Raspberry Stems (*Rubus Idaeus*, L) and Grape Pruning Residues (*Vitis Vinifera*, L). *International Journal – Wood, Design & Technology*, 4(1), pp. 1–8.
- MIHAJLOVA, J. 2020. Optimization of Pressing Mode of Particleboards with Beech Raw Material in the Composition. *9th Hardwood Conference Proceedings*, pp. 183–186.
- MOHANTY, A. K., VIVEKANANDHAN, S., PIN, J., M., MISRA, M. 2018. Composites from Renewable and Sustainable Resources: Challenges and Innovations. *Science* 362, pp. 536–542.
- PALLESEN, B. E. 1996) The Quality of Combine-Harvested Fibre Flax for Industrials Purposes Depends on the Degree of Retting. *Industrial Crops and Products* (5), pp. 65–78, Elsevier.
- RÉH, R., VRTIELKA, J. 2013. Modification of the core layer of particleboard with hemp shives and its influence on the particleboard properties, *Acta Facultatis Xylogologiae* 55(1), pp. 51–59.
- SACKEY, E. M., SEMPLE, K. E., OH, S. W., SMITH, G. D. 2008. Improving Core Bond Strength of Particleboard Through Particle Size Redistribution. *Wood and Fiber Science*, 40(2), 2008, pp. 214–224.
- VALYOVA, M., KOYNOV, D. 2020. Influence of Pressing Time on Physical and Mechanical Properties of Particleboards Made from Scots Pine (*Pinus sylvestris* L.). *European Mechanical Science*, 4(2), pp. 78–81. DOI: 10.26701/ems.532796.
- ZVIRGZDS, K., KIRILOVS, E., KUKLE, S., GROSS, U. 2022. Production of Particleboard Using Various Particle Size Hemp Shives as Filler. *Materials*, MDPI, 15, 886. DOI: 10.3390/ma15030886.
- EUROPEAN COMMITTEE FOR STANDARDIZATION 1999. *Wood-based panels – determination of modulus of elasticity in bending and of bending strength. EN 310*, Brussels.

EUROPEAN COMMITTEE FOR STANDARDIZATION.  
2010. Particleboards – Specifications. EN 312, Brussels.

EUROPEAN COMMITTEE FOR STANDARDIZATION.  
2009. Wood fibreboards - Definition, classification and symbols. EN 316, Brussels.

EUROPEAN COMMITTEE FOR STANDARDIZATION.  
1998. Particleboards and fibreboards – determination of swelling in thickness after immersion in water. EN 317, Brussels.

EUROPEAN COMMITTEE FOR STANDARDIZATION.  
1993. Particleboards and fibreboards; determination of tensile strength perpendicular to the plane of the board. EN 319, Brussels.

EUROPEAN COMMITTEE FOR STANDARDIZATION.  
2001. Wood-based panels – determination of density. EN 323, Brussels.

FAO. FOREST PRODUCT STATISTICS. Available Online at: <http://www.fao.org/forestry/statistics/> (accessed on June 2022).



UNIVERSITY OF FORESTRY

FACULTY OF FOREST INDUSTRY



# **INNOVATION IN WOODWORKING INDUSTRY AND ENGINEERING DESIGN**

**1/2022**

INNO vol. XI Sofia

ISSN 1314-6149  
e-ISSN 2367-6663

Indexed with and included in CABI

# INNOVATION IN WOODWORKING INDUSTRY AND ENGINEERING DESIGN

Science Journal

Vol. 11/p. 1–74

Sofia 1/2022

ISSN 1314-6149

e-ISSN 2367-6663

Edition of

**FACULTY OF FOREST INDUSTRY – UNIVERSITY OF FORESTRY – SOFIA**

**The Scientific Journal is indexed with and included in CABI.**

## SCIENTIFIC EDITORIAL BOARD

Alfred Teischinger, PhD (Austria)  
Alexander Petutschning, PhD (Austria)  
Anna Danihelová, PhD (Slovakia)  
Antonios Papadopoulos, PhD (Greece)  
Asia Marinova, PhD (Bulgaria)  
Biborka Bartha, PhD (Romania)  
Bojidar Dinkov, PhD (Bulgaria)  
Danijela Domljan, PhD (Croatia)  
Desislava Angelova, PhD (Bulgaria)  
Derya Ustaömer, PhD (Turkey)  
George Mantanis, PhD (Greece)  
Ivica Grbac, PhD (Croatia)  
Ivo Valchev, PhD (Bulgaria)  
Ján Sedliačik, PhD (Slovakia)  
Julia Mihajlova, PhD (Bulgaria)  
Hubert Paluš, PhD (Slovakia)  
Hülya Kalaycioğlu, PhD (Turkey)  
Ladislav Dzurenda, PhD (Slovakia)  
Luboš Krišták, PhD (Slovakia)

Marius Barbu, PhD (Romania)  
Muhammad Adly Rahandi Lubis, PhD (Indonesia)  
Nencho Deliiski, DSc (Bulgaria)  
Neno Tritchov, PhD (Bulgaria)  
Pavlin Vitchev, PhD (Bulgaria)  
Pavlo Bekhta, PhD (Ukraine)  
Petar Antov, PhD (Bulgaria)  
Regina Raycheva, PhD (Bulgaria)  
Roman Réh, PhD (Croatia)  
Ružica Beljo Lučić, PhD (Croatia)  
Silvana Prekrat, PhD (Croatia)  
Štefan Barčík, PhD (Slovakia)  
Svetoslav Anev, PhD (Bulgaria)  
Valentin Shalaev, PhD (Russia)  
Vasiliki Kamperidou (Greece)  
Vesselin Brezin, PhD (Bulgaria)  
Victor Savov, PhD (Bulgaria)  
Vladimir Koljozov, PhD (Macedonia)  
Zhivko Gochev, PhD (Bulgaria)

## EDITORIAL BOARD

N. Trichkov, PhD – Editor in Chief  
D. Angelova, PhD – Co-editor  
N. Minkovski, PhD

V. Savov, PhD  
P. Vitchev, PhD

**Cover Design: DESISLAVA ANGELOVA**

**Printed by: INTEL ENTRANCE**

**Publisher address: UNIVERSITY OF FORESTRY – FACULTY OF FOREST INDUSTRY**

**Kliment Ohridski Bul., 10, Sofia, 1797, BULGARIA**

**<http://inno.ltu.bg>**

**<http://www.scjournal-inno.com/>**

## CONTENTS

BUILDING EXPERT MAPS FOR ERGONOMETRIC, COMPOSITIONAL AND COLORS SCHEME EVALUATION OF MACHINE CONTROL PANELS .....	5
Aleksandrina Bankova, Zoya Tsoneva	
THE TRIPOD: A RARELY MENTIONED FURNITURE TYPE.....	13
Regina Raycheva, Desislava Angelova	
CHANGE IN THE DURATION OF AUTOCLAVE STEAMING REGIMES OF NON-FROZEN PRISMS AT DISPATCHING INTERVENTIONS IN THE PRODUCTION OF VENEER .....	25
Nencho Deliiski, Dimitar Angelski, Pavlin Vitchev, Natalia Tumbarkova	
IDENTIFICATION OF THE COLOR FALSE HEARDWOOD OF <i>FAGUS SYLVATICA</i> L. IN THE COLOR SPACE CIE L*A*B* .....	33
Ladislav Dzurenda, Michal Dudiak	
RECYCLING OF MEDIUM DENSITY FIBREBOARDS – A REVIEW .....	39
Christian Panchev, Viktor Savov	
PROPERTIES OF PARTICLEBOARDS WITH THE PARTICIPATION OF HEMP AND VINE PARTICLES IN THE CORE LAYER – PART I: EFFECT OF THE COMPOSITION.....	47
Rosen Grigorov, Viktor Savov, Slavcho Alexandrov	
ABSTRACT METHODS TO CLASSIFY THE STRUCTURE OF WOOD .....	57
Nikolai Bardarov, Vladislav Todorov, Tanya Pancheva	
STUDY ON DURABILITY OF TUNGSTEN CARBIDE CUTTER HEADS .....	65
Zhivko Gochev, Pavlin Vitchev, Georgi Vukov	
SCIENTIFIC JOURNAL „INNOVATIONS IN WOODWORKING INDUSTRY AND ENGINEERING DESIGN“ .....	72