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Bonding of sawmill birch wood with selected biopolymer-based glues

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Abstract: *Bonding of sawmill birch wood with selected biopolymer-based glues*. The aim of the research was to determine the shear strength and in-wood damage share of birch lamellas with the surface shaped by rotary saw cutting and bonded with the use of selected biopolymers, such as gelatine, caseine, gluten and polyvinyl acetate (PVAc), as a reference bonding material. The results show that the highest shear strength was achieved in case of PVAc glue used as a binder. From the tested group of biopolymers, a gelatine/acetic acid mixture gave the highest strength.

Keywords: solid wood, bonding, biopolymer, gelatine, caseine, gluten, surface roughness, shear strength

INTRODUCTION

Due to a growing demand to decrease the dependence on oil-based resources, more attention is being paid to the possibilities of developing the production of polymeric materials from biobased resources (Díaz López and Montalvo 2015). This approach has caused a renewed interest in conventional, traditional biobased binders (Finlay 2008). Biocomposites are considered to be promising alternatives to commonly used, petro or oil-based, polymers. “Green” composites can minimize the negative impact on the environment throughout their entire life cycle. Specifically, they provide a solution to such current environmental problems as environmental pollution, depletion of fossil resources and greenhouse gas emission (Yu et al. 2006, Bugnicourt et al. 2014). The above-mentioned biopolymers have also potential to become a real replacement of conventional wood binders, as they are mostly produced from oil-based raw materials. Moreover, in the light of the research by Liu et al. (2019), the wood-polymer adhesion can be supported by mechanical fixing/anchoring of these materials, which supports the connection strength. This can be improved by using wood with specific roughness of the surface, but.

The aim of the research was to determine the shear strength and in-wood damage share of the birch lamellas with their surface shaped by rotary saw cutting and bonded with the use of selected biopolymers, such as gelatine, caseine, gluten and polyvinyl acetate, (PVAc) as a reference bonding material.

MATERIALS AND METHODS

Bonding of the lamellas

Not less than 12 overlap samples made of air-dried birch (*Betula pendula* Roth) lamellas with dimension of 110x22x7 mm^3 and with sawmill surface roughness (R_a=13.66 μm, R_y=98.63 μm, R_q=18.13 μm, measured by Gumowska and Kowaluk 2019) were prepared for every biobased polymer mentioned below: gelatine (edible, commercially available, animal origin) mixed with 3.2% fat milk (3:1 w/w, gelatine : milk, respectively) or with 10% acetic acid (1:1 w/w), caseine (cow milk origin) with hydrated lime (5:1 w/w, caseine : lime, respectively + water to dissolute), gluten, as well as for industrial D3 class polyvinyl acetate (PVAc) glue as a reference bonding material. The excessive amount of above-mentioned binders was applied onto the lamellas at a room temperature. Then, every two lamellas, with the binder spread on one lamella, have been connected and pressed with the use of hand carpentry clamp for 24h to remove the surplus of polymer and to stabilize the connection.

Shear strength testing and in-wood damage evaluation

The shear strength of the produced samples was measured using standard universal testing machine, where the samples were loaded by tension to be broken within 60±30 s, and the maximum load [N] was recorded. Prior to the loading, the real dimensions of the bonding line were measured. The shear strength was calculated as a maximum load [N] referred to the bonding line area [mm^2]. After the break of the sample, every damaged zone was analyzed to see if the break occurred in the wood structure, and the area of in-wood destruction was visually assessed (in % of total bonding line area).

Samples conditioning

All the tested samples were conditioned prior to the testing in 20°C/65% RH to achieve a constant weight.

Statistical assessment

The results of all the tested features, excluding the density profile, were evaluated statistically using Fisher's exact test, with probability level $p=0.05$, to establish whether the achieved average values were statistically equal. Where applicable, the mean values of the investigated features and the standard deviation, indicated as error bars on the plots, were presented.

RESULTS

Shear strength testing and in-wood damage evaluation

The results of shear strength measurement of birch lamellas bonded with use of selected biopolymers are presented in figure 1.

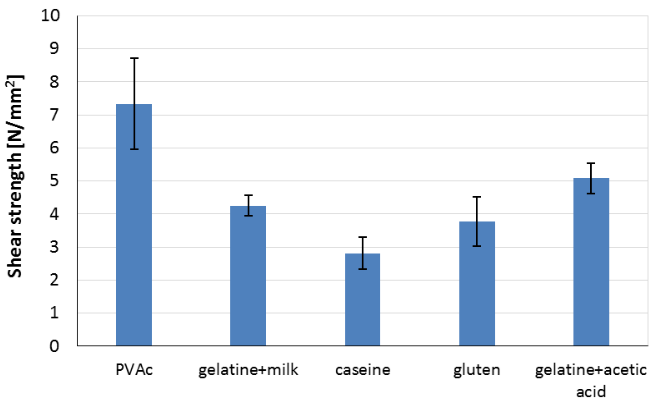

Figure 1. Shear strength of tested samples

The highest average value of shear strength is 7.34 N/mm^2 for birch lamellas bonded by PVAc as the reference glue, while the lowest strength value of 2.82 N/mm^2 is obtained for caseine glue. The highest shear strength among all the tested biobased glues is 5.08 N/mm^2 and was recorded for gelatine/acetic acid blend. The higher strength of gelatine/acetic acid binder could be explained by better mechanical adhesion between the binder and the surface, which has high (regarding wood surface bonded in furniture industry) roughness parameters mentioned above. In the light of high R_y parameter of the tested birch lamellas, this feature should influence positively the strength of the prepared connection due to the fact that wood-polymer adhesion can be supported by mechanical fixing of these materials, in particular because gelatine/acetic acid blend was easily spread on the lamellas, better than the remaining binders. Better bonding thanks to higher surface roughness was proved when bonding poplar wood with HDPE with the use of chlorinated PP (Liu et al. 2019). The influence of the roughness parameters (R_a, R_z and R_{max}) on the bonding strength have been also confirmed for pine, oak and nyatoh wood (Hiziroglu et al. 2014). The researchers found that for oak and nyatoh the bonding strength increases as R_a increases. Considering the values of standard deviations (error bars on the plot), it can be noted that the mean values of shear strength are statistically different between each variant of the group of biopolymer when compare to PVAc. In group of biopolymers, the average value of shear strength of caseine glue is statistically different that gelatine/milk and gelatine/acetic acid.

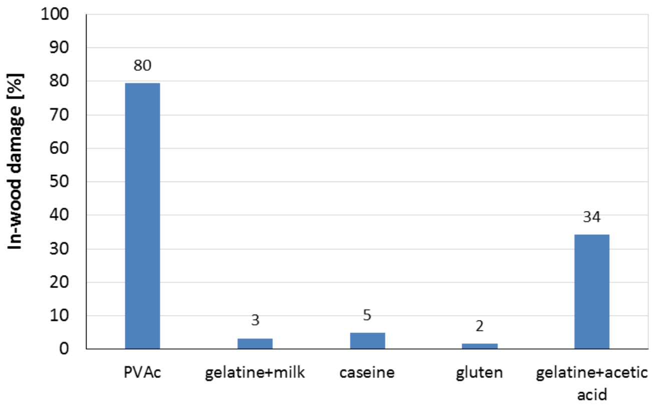

Figure 2. In-wood damage of the tested samples

The results of in-wood damage assessment for the tested samples are presented in figure 2. The highest share of failure in wood structure (80%) was noted for the reference glue. With regard to the biobased binders, the best results were found for gelatine/acetic acid (34%). The remaining biobased binders connection failures occur in bonging line structure, which indicates low cohesion forces for these materials/blends. The examples of the break zone of tested samples are presented in figure 3.

CONCLUSIONS

According to the conducted research and the analysis of the obtained results, the following conclusions and remarks can be drawn:

1. The roughness of the birch lamellas can support the high bonding strength of wood with biobased binders.
2. Easier spread of gelatine/acetic acid binder can be responsible for higher connection strength, measured as shear strength.
3. The shear strength of the tested biobased polymer binders is significantly lower than that of the industrial reference glue PVAc.

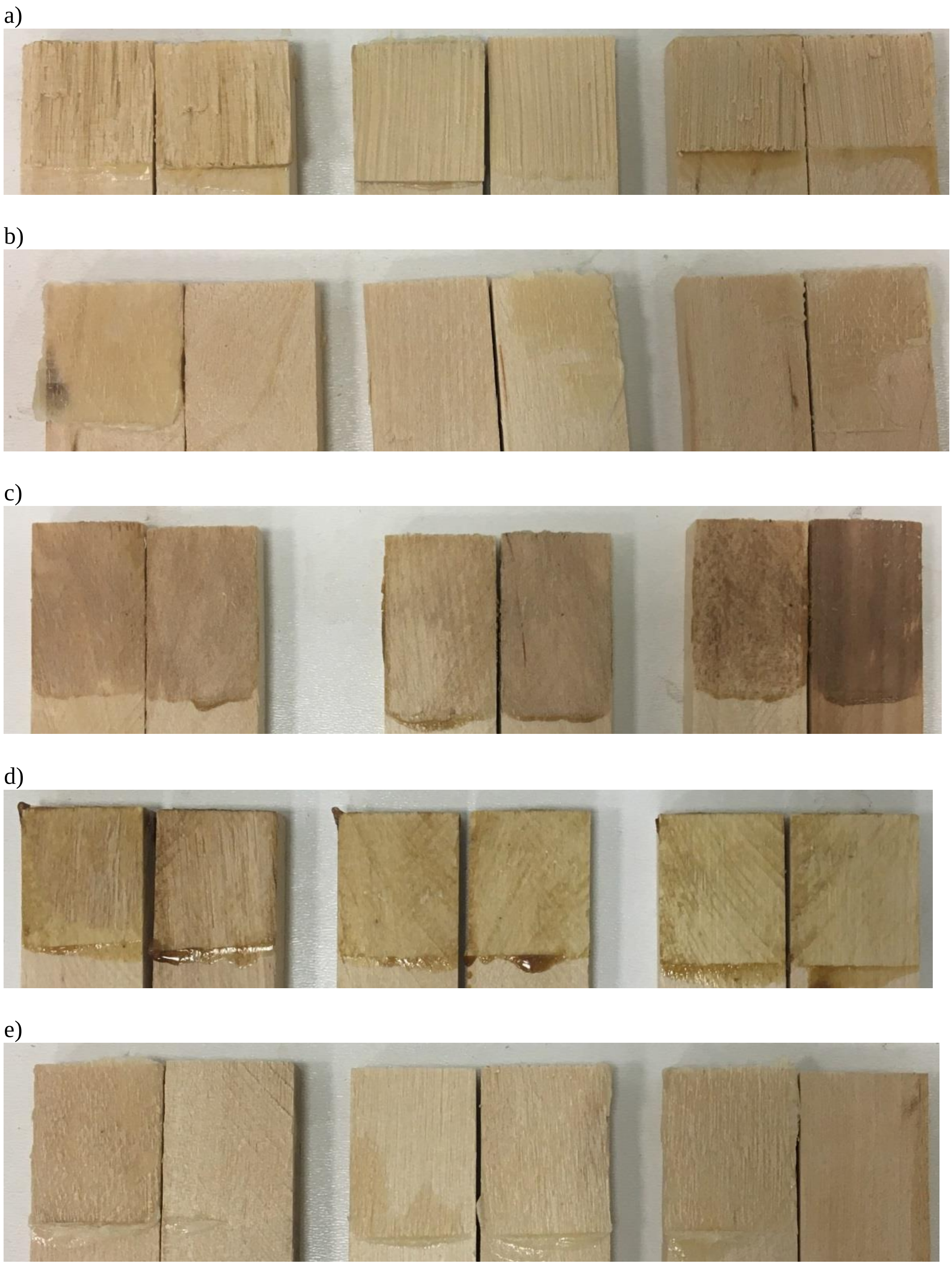

Figure 3. Examples of break zone of the tested samples bonded with a) PVAc, b) gelatine+milk, c) caseine, d) gluten, e) gelatine+acetic acid

REFERENCES

1. BUGNICOURT E., CINELLI P., LAZZERI A., ALVAREZ V., (2014). Polyhydroxyalkanoate (PHA): review of synthesis, characteristics, processing and potential applications in packaging. Express Polym Lett 8(11):791–808; DOI: 10.3144/expresspolymlett.2014.82
2. DÍAZ LÓPEZ, F. J., AND MONTALVO, C. (2015). A comprehensive review of the evolving and cumulative nature of eco-innovation in the chemical industry. Journal of

Cleaner Production Volume 102, pp. 30 –43; DOI:10.1016/j.jclepro.2015.04.007
3. FINLAY M.R. (2008). Old Efforts at New Uses: A Brief History of Chemurgy and the American Search for Biobased Materials. Journal of Industrial Ecology, Massachusetts Instituteof Technology and Yale University, Volume 7, Number 3–4, pp. 33–46; DOI:10.1162/108819803323059389
4. GUMOWSKA, A., AND KOWALUK, G. (2019). Bonding of birch solid wood of sawmill surface roughness with use of selected thermoplastic biopolymers. Annals of WULS - SGGW. Forestry and Wood Technology 2019, No. 106, pp. 9–15
5. HIZIROGLU, S., ZHONG, Z. W., AND ONG, W. K. (2014). Evaluating of bonding strength of pine, oak and nyatoh wood species related to their surface roughness, Measurement: Journal of the International Measurement Confederation. DOI: 10.1016/j.measurement.2013.11.053
6. KOWALUK, G., AND WRONKA, A. (2018). Density – induced Surface roughness of dry formed fibreboards, Ann. WULS – SGGW, For and Wood Technol. 102, Annals of Warsaw University of Life Sciences – SGGW, Forestry and Wood Technology No. 102: pp. 75–81
7. LIU, Y., LI, X., WANG, W., SUN, Y., AND WANG, H. (2019). Decorated wood fiber/high density polyethylene composites with thermoplastic film as adhesives, International Journal of Adhesion and Adhesives. DOI: 10.1016/j.ijadhadh.2019.05.008
8. YU .L, DEAN K., LI L., (2006). Polymer blends and composites from renewable resources. Progress in Polymer Science 31(6) :pp. 576–602; DOI: 10.1016/j.progpolymsci.2006.03.002

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Streszczenie: *Łączenie tarcicy brzozowej z użyciem wybranych spoiw biopolimerowych.* Celem badań było określenie wytrzymałości na ścinanie i udziału uszkodzeń drewna lameli brzozowych o powierzchni ukształtowanej na pilarce tarczowej i spojonych przy użyciu wybranych biopolimerów, takich jak żelatyna, kazeina, gluten i polioctan winylu (PVAc) jako referencyjny materiał wiążący. Wyniki badań wykazały, że najwyższą wytrzymałość na ścinanie uzyskano w przypadku kleju PVAc, jako spoiwa. Z grupy biopolimerów mieszanina żelatyna / roztwór kwasu octowego dała najwyższą wytrzymałość na ścinanie.

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