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Post-extraction birch bark residues as a potential binder in particleboards

ALEKSANDRA JEŻO[1], ANITA WRONKA[2]

[1] Faculty of Wood Technology, Warsaw University of Life Sciences-SGGW, Warsaw, Poland
[2] Department of Technology and Entrepreneurship in Wood Industry, Institute of Wood Sciences and Furniture, Warsaw University of Life Sciences – SGGW

Abstract: *Post-extraction birch bark residues as a potential binder in particleboards*. Nowadays, in the wood-based composites industry, aspects such as ecology and joining the current circular economy play a very important role. However, user safety is also very important. Formaldehyde is one of the hazardous substances which, if emitted too high, can harm human health. Unfortunately, binders containing formaldehyde still reign supreme in the wood-based panels' industry. Therefore, this paper concerns the possibility of using post-extraction residues obtained during the extraction of suberinic acid, as a formaldehyde-free and ecological binder in the production of particleboards. The main component, suberinic acid, is a colorless, crystalline solid used in the synthesis of drugs and the production of plastics. The aim of the research was to answer the question: since suberinic acid itself is a good binder in the production of particle boards, as described in other publications, it is worth checking whether the post-extraction residues also have similarly good properties of joining particles in particle boards, depending on the size of the wood particles? In addition, the use of post-extraction residues of bark, and thus the elimination of synthetic adhesives in the wood-based composites production process, allows the reuse of wood raw material, which fits perfectly with the idea of upcycling. The tests showed that using post-extraction residues of birch bark, using 10% and 20% resination, the requirements of the EN 312: 2010 standard were met only in the case of the modulus of elasticity for boards made of the largest wood particles used in the tests. The resination and the size of wood particles contributed to the improvement of the properties of the tested boards.

Keywords: particleboard, glue, binder, formaldehyde, UF, bark, upcycling

INTRODUCTION

Currently, birch bark is a typical byproduct of the birch plywood industry which is a well-developed industry in many countries. Birch bark is usually burned to produce heat and thus a significant amount of carbon dioxide is released into the atmosphere. The problem with the production technology is the fact that synthetic resin is used when gluing plywood. Synthetic resin is very beneficial, but due to the formaldehyde emission (FA) can be a toxic product for both producers and users (RIZHIKOVS and PAZE, 2019).

The outer bark of birch (*Betula pendula*) contains up to 45% (dry base) of suberin and has been recognized as a promising source of suberinic acids (SA), where the binding potential has been proven. Suberin acid-based adhesive from outer birch bark as an alternative to synthetic adhesives for the production of particleboards was obtained and wildly characterized. Glue prepared in a water solution and precipitated with LCC significantly turned out to improve humidity resistance and mechanical properties of the resulting particleboards (RIZHIKOVS *et al*. 2022).

In the study conducted by TUPCIAUSKAS *et al.* (2019) PB was obtained from a mixture of combined birch wood particles with a new natural formaldehyde-free suberinic acid-based binder which is simply available and useful without any additions. A binder was prepared from the residue extracted with ethanol and hydrolytically depolymerized outer birch bark which melts and shows good thermal stability and cures at a temperature of about 205°C and generally includes carboxylic acids, alcohol groups, aliphatic groups, and suberin ester groups, conjugated aromatic carbonyl groups, vinyl groups, and polysaccharides. The boards obtained have met the requirements of the non-load-bearing standard PB for use in humid conditions (EN 312 P3-type panel).

Processing possibilities of birch outer bark into green bio-composites have been described also by PAZE *et al.* (2017). A significant impact on the plate material density and flexural strength were demonstrated by the amount of binder and pressure but the pressing temperature was of less importance. Preliminary data showed an increase in pressing temperature from 160°C to 200°C under the pressure of 3.5 MPa resulting in a slight increase in density and bending strength.

MAKARS *et al.* (2021) investigated furfural formation (FUR) and mechanical properties of suberinic acids-bonded particleboards depending on their preparation parameters and they concluded that glycerol as an additive in some cases only slightly decreased the FUR content. By increasing the amount of glycerol, the mechanical properties of PB also deteriorated. By reducing the acidity of the adhesive from pH 3 to 6, it was possible to obtain boards that have more than 6 times lower FUR performance at 230°C and meet the requirements of EN 312 P2-type panels for interior panels equipment to which exposure of FUR must not have harmful effects for humans.

The studies on the possibilities of using other types of non-formaldehyde binders in particleboard production have also been carried on before.

Particleboards bound with citric acid and sucrose were manufactured to test the feasibility of the natural glue. The glue used was an aqueous solution in which citric acid and sucrose were dissolved. Mechanical properties and water resistance increased with the proportion of sucrose. In this study, the optimal mixture of citric acid and sucrose and optimal resin content was 25-75 and 30 wt.%, Respectively. Modulus of rupture (MOR), internal bond (IB), and thickness swelling (TS) of the board produced with the optimal proportion of ingredients were comparable to or higher than the control requirement. The IB strength was over 1.5 MPa and the board showed good water resistance, indicating an excellent adhesive system (UMEMURA *et al.* 2013).

UMEMURA and ZHAO (2014) examined the ratio of tannin to sucrose, drying effect after spraying, and resin content on the properties of particle boards. Properties were strengthened when drying was carried out after spraying and when the sucrose ratio increased. Based on the results obtained, the optimal proportion of tannins to sucrose was 25/75 and the optimal resin content was between 30 and 40 wt.% When the particleboards were produced under optimal conditions, they showed excellent mechanical properties, higher than required for JIS A 5908 type 18.

Advantages of benzoxazines and their resins are extremely easy to design structure and relationship between structure and properties adapted to the demand for naturally available materials or wasteful by-products, and then polymers with the desired properties. Biomass is a renewable and alternative source for the production of fuels and chemicals, including a complex of phenols with various groups that have found their way into the synthesis of benzoxazine resins. Cellulose, lignin, and chitosan as bio-macromolecules with high availability (LYU and ISHIDA, 2019).

FERREIRA *et al.* (2019) confirmed that a binder made of coarse spent sulfite liquor and a mixture of wheat flour works as a good adhesive for particleboards. All panels produced were in accordance with the requirements of IB of EN 312 for particle boards of type P2. Regarding the stability of the resin, particleboards made of the binder showed good internal bond strength after 30 days, above the IB requirements of the EN 312 standard for particleboard type P2.

Composite materials have been successfully made from vegetable oil-based resin and fiber with mechanical and physical properties desirable in many applications. Dynamic mechanical analysis tests showed that with natural fiber reinforcement, storage module soybean oil resin improved more than fivefold from waste paper. These natural composites were found to have mechanical strength suitable for applications such as housing and automotive (O'DONNELL *et al.* 2004).

KARIM *et al.* (2020) in their study on the properties of native and blended oil palm starch with nano-silicon dioxide as a binder for particleboard, confirmed that blended palm oil starch with polyvinyl alcohol and nano-silicon dioxide (SiO_2) had a significant influence on the physicochemical properties. Both native starch and mixed oil palm starch properties positively influenced the final yield of particleboard as a binder. The ratio of starch content also affected the mechanical properties of particleboard. In this study, all particle board panels were glued using native and mixed palm oil starch that complies with Japanese Industry Standards (JIS) Type 8 for mechanics properties including MOE, MOR, and IB.

In the studies conducted by SANTOSO *et al.* (2019), the optimal conditions were achieved on a citric acid bonded particleboard with hot water extraction. Tensile modulus, modulus of elasticity, internal bond, and thickness the swelling of the board produced under optimal conditions was comparable to or greater than the type 8 requirement of JIS A 5908: 2003. Hot water extraction treatment on a binder of maltodextrin and sucrose particleboard has significantly reduced physical and mechanical properties. In citric acid bonded particleboard, the value was increased by hot water extraction. The n-hexane extraction treatment has a different physical and mechanical effect.

MATERIALS AND METHODS

Single-layer particleboards with a nominal density of 700 kg/m^3 were produced. There were two variants of resination – 10% and 20%. The thickness of the panels produced equaled 10 mm. The initial dry mass content of the binder was 25% and the working dry mass content of the binder was 20%. No hydrophobic agent was added. The temperature of pressing of the panels equaled 180ºC and the maximum unit pressure was 2.5 MPa. Pressing time equaled 40 s/mm of the nominal panel thickness.

There were three types of particles used:

- fine (as for industrial 3-layers face layers production)
- medium (as for industrial 3-layers core layers production)
- coarse (as for industrial OSB production)

The wood raw material used for particle production was mainly *Pinus sylvestris* L. The bulk density of fine and medium particles has been shown by Wronka *et al.* 2021. The binding agent used in the study was kindly provided by the Latvian State Institute of Wood Chemistry, Riga, Latvia, and has been made from the residues resulting from the isolation of suberinic acid, under the process described by MAKARS *et al.* 2022. The outer bark of a birch tree contains a large amount of lupane triterpenes extracts (betulin, lupeol, betulinic acid) that can be isolated by various methods. The most common method is alkaline hydrolysis in water and other solvents such as isopropanol. After removing the extracts, mainly from suberin-containing external protective agents' tissue is left.

Mechanical and physical properties testing

The following mechanical parameters of produced panels were investigated: modulus of rupture (MOR) and modulus of elasticity (MOE) during bending, according to EN 310:1994, tensile strength perpendicular to the plane of the board (internal bond, IB) according to EN 319:1993, screw withdrawal resistance (SWR) according to EN 320:2011. A number of 10 samples of every panel type were used for mentioned tests. The following physical properties of produced panels were investigated: swelling in thickness (TS) and water absorption (WA) after immersion in water according to EN 317:1993 standard (not less than 10 samples of every panel type used) and density profile with the use of the Grecon DA-X unit, of sampling step

0.02 mm, measuring speed 0.1 mm/s (3 samples of every panel type used; most representative profile presented then on the plot). All the tested panels have been conditioned prior to the tests in 20°C/65% RH to constant weight. The obtained results were examined through the analysis of variance (ANOVA) and the Student's test was carried out ($\alpha = 0.05$) to determine the statistical significance of differences between the factors. The results presented in the graphs (where applicable) show mean values and standard deviations.

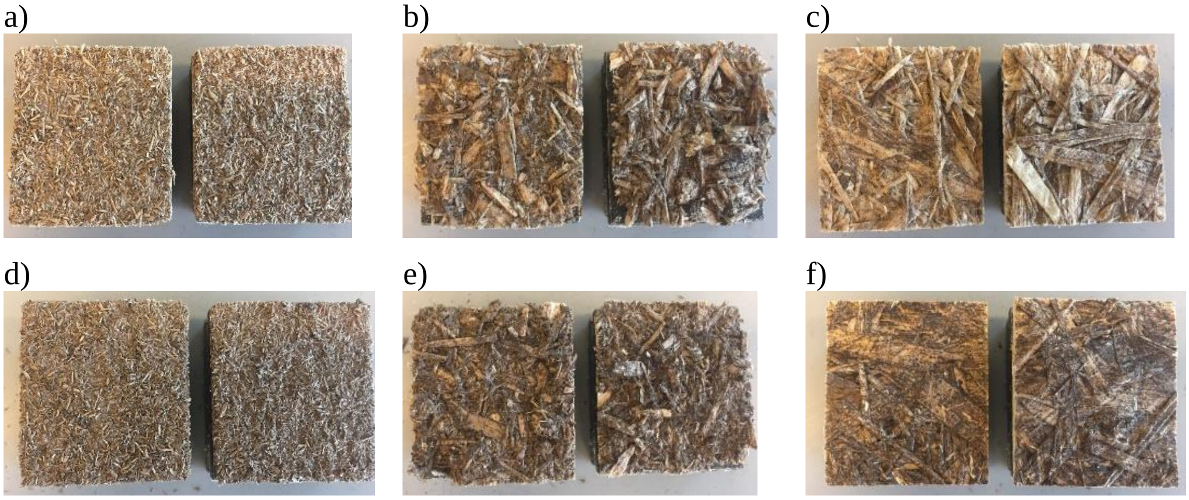

Figure. 1. Single-layer panels produced (here - after IB test): a – fine particles 10% resination; b – medium particles 10% resination; c – coarse particles 10% resination; d – fine particles 20% resination, e – medium particles 20% resination, f – coarse particles 20% resination; the size of the samples: 50 mm x 50 mm

RESULTS AND DISCUSSION

Density profile

In figure 2 there are density profiles of panels produced illustrated. The particleboards made of medium particles showed profiles closest to U-shaped, however, it is not possible to talk about any clear rule in shapes. Medium-particle boards with a resination of 10% had the highest density values at the panel surface, although the density did not distribute symmetrically over the thickness. The extreme values were around 750 and 900 kg/m^3. In the center of the sample, the density was approximately 550 kg/m^3. In the case of panels with the same type of particle but with a resination equal to 20%, the highest values occurred close to the surface of the boards, but at extreme points, the density values dropped sharply to reach about 600 and 700 kg/m^3. At the peak points, the density was 800 kg/m^3, and at the least dense point - about 550 kg/m^3. In the case of other samples, it is also not possible to speak of a U-shaped course. However, the board with a coarse particle and the resination of 10% showed a density profile similar to the U-shaped one, reaching asymmetrically at the surface of the board – 900 and 800 kg/m^3, while in the middle - about 500 kg/m^3 at the least dense point. However, this point was not perfectly located in the middle of the plate thickness. In samples with the same particle, but with the resination equal to 20%, a completely different course of the density distribution can be observed, here the highest value occurs more or less in the half of the board - over 800 kg/m^3, while the extreme values were around 600 and less than 800 kg/m^3. Moving on to the boards with the fine particles, their density distribution along the thickness was very irregular. The boards with the resination of 20% showed the highest density values equal to over 800 kg/m^3 and the smallest - below 600 kg/m^3. Boards with fine particles and a resination of 10% reached a maximum of less than 800 kg/m^3, and in the least dense punch - less than 600 kg/m^3. All tested variants had an average density close to 700 kg/m^3, as assumed nominal density.

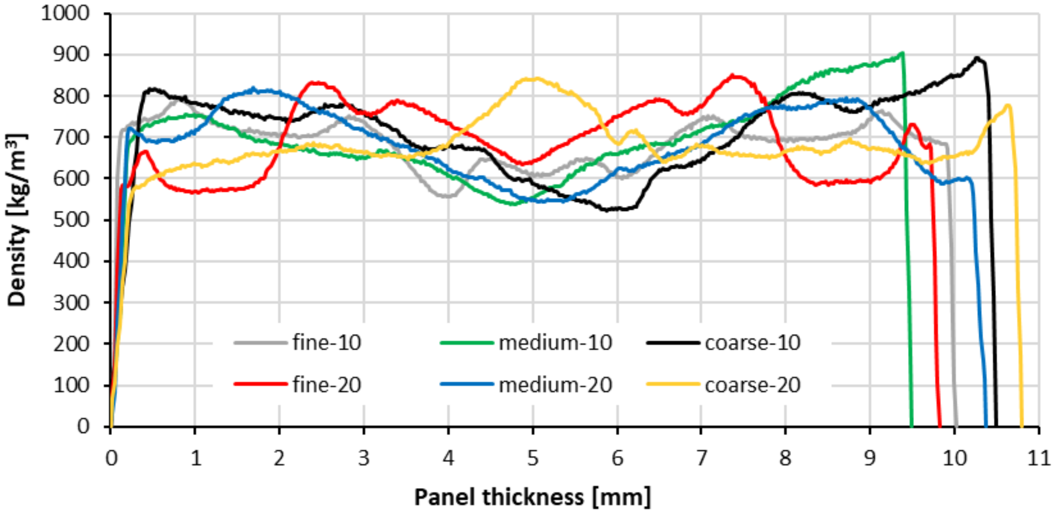

Figure 2. Density profiles of examined panels

Modulus of rupture and modulus of elasticity

In figure 3 the results of the examination of MOR values have been shown. The highest MOR values were observed for medium-particle particleboards, where for the resination equal to 20%, this value was higher than by less gluing share - 6.44 N/mm^2, and for the resination of 10% - 5.78 N/mm^2. Particleboards with fine particles also showed higher MOR in the case of a higher resination, and so, for 20%, the value of the tested parameter was 4.90 N/mm^2, while for 10% of resination - 3.67 N/mm^2. In the case of the boards with the coarse particles, the situation was the opposite, because in this case the higher MOR was obtained for the resination of 10% and it amounted to 4.49 N/mm^2, while for 20% of the bonding - 4.18 N/mm^2. The minimum MOR requirements for P2 – type panels according to EN 312:2010 standard is 11 N/mm^2. That means none of the tested panel meet this requirement. The statistically significant differences in mean MOR value among the same resination have been found for medium particle type referred to as remaining particle type panels. When analyzing the particles type, the statistically significant differences in mean MOR value have been found only for fine particle samples. FERRANDEZ-GARCIA *et al*. (2019) in the research on the use of citric acid as a natural binder in the production of PB noted that the higher the binder content, the higher the MOR value. This conclusion has also been confirmed in other studies by MARAGHI *et al*. (2018) where the properties of particleboards made with urea-formaldehyde resination at levels 9% and 11% have been examined.

In figure 4 the results of the examination of MOE values have been shown. The highest values of the modulus of elasticity were shown by the boards with the coarse particles. The boards with the lower resination, 10%, had higher MOE values, of 2205 N/mm^2, while those with the resination equal to 20%, showed MOE of 2011 N/mm^2. The medium-particle particleboards had MOE of 614.2 N/mm^2 for 10% resination and 245.3 N/mm^2 for 20% resination. The lowest values of the modulus of elasticity were shown for the fine-particle particleboards - 252.0 N/mm^2 for 10% bonding and 164.2 N/mm^2 for 20% bonding. The minimum MOE requirements for P2 – type panels according to EN 312:2010 standard is 1800 N/mm^2. That means, the only coarse type particleboards, both resination, meet this requirement. The only statistically insignificant differences in mean MOE value among the same particle type have been found for coarse particle types referred to as remaining particle type panels. All remaining mean MOE values have been statistically significantly different from another. WARMBIER and WILCZYŃSKI (2016) showed in their studies that increasing the urea-formaldehyde resin content in one-layer particleboard increases MOR as well as MOE which is not the rule in our case by bonding with suberinic acid residues.

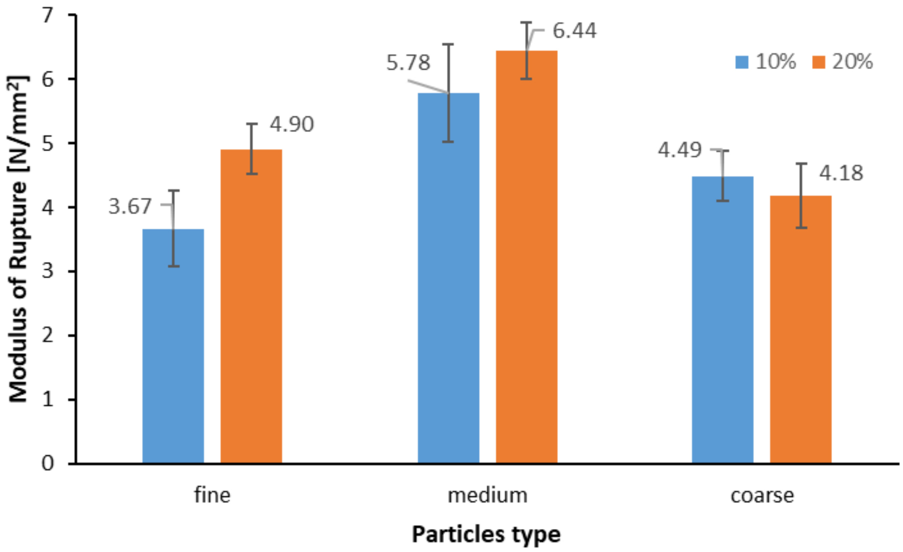

Figure 3. Modulus of Rupture (MOR) of the examined particleboards

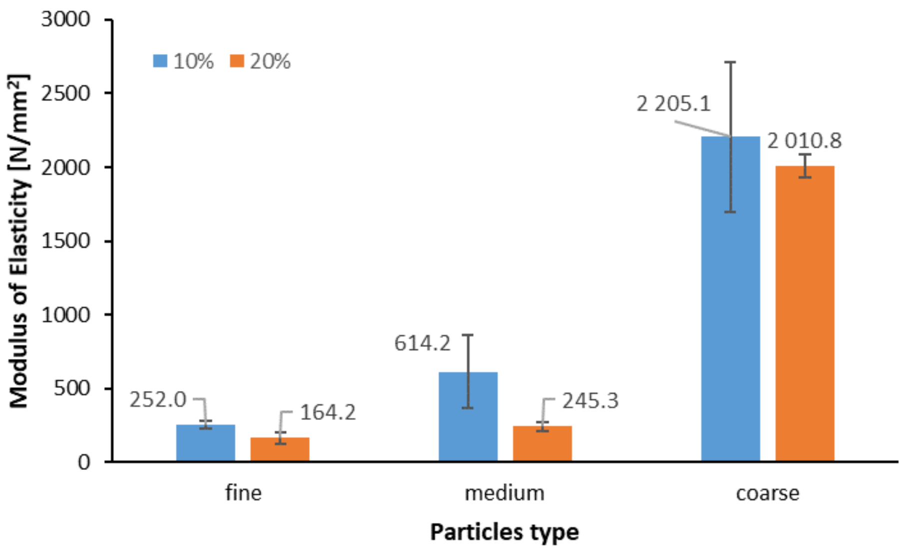

Figure 4. Modulus of Elasticity (MOE) of the examined particleboards

Internal Bond

In figure 5 the obtained results for IB of the panels produced have been illustrated. The highest IB values were shown by samples with medium particles and a resination of 20%, equaling 0.25 N/mm^2. Boards with the same particle type but resination of 10% had IB of 0.22 N/mm^2. The particleboards with the coarse particles showed IB of 0.22 N/mm^2 for a resination of 20% and 0.20 N/mm^2 for a resination of 10%. As for the boards with fine particles, the resination of 20% IB was 0.20 N/mm^2, and the resination of 10% - 0.19 N/mm^2. The minimum IB requirements for P2 – type panels according to EN 312:2010 standard is 0.40 N/mm^2. That means none of the tested panel meet this requirement. The only statistically significant differences in mean IB value have been found among the same resination between fine and medium particle type 20% resinated panels.

SACKEY *et al.* (2008) have investigated the relation between the particle size distribution and the internal bond of single-layer PB. The findings partially refuted their hypothesis that increasing fines will increase IB strength. It is rather the combination of compaction ratio and packing efficiency that cause an increase in the properties, so no rule for particleboard containing only fine particles. However, as examined in the studies conducted by MARASHDEH *et al.* (2011) on binderless particleboards with different particle sizes, IB increased with decreasing the particle size.

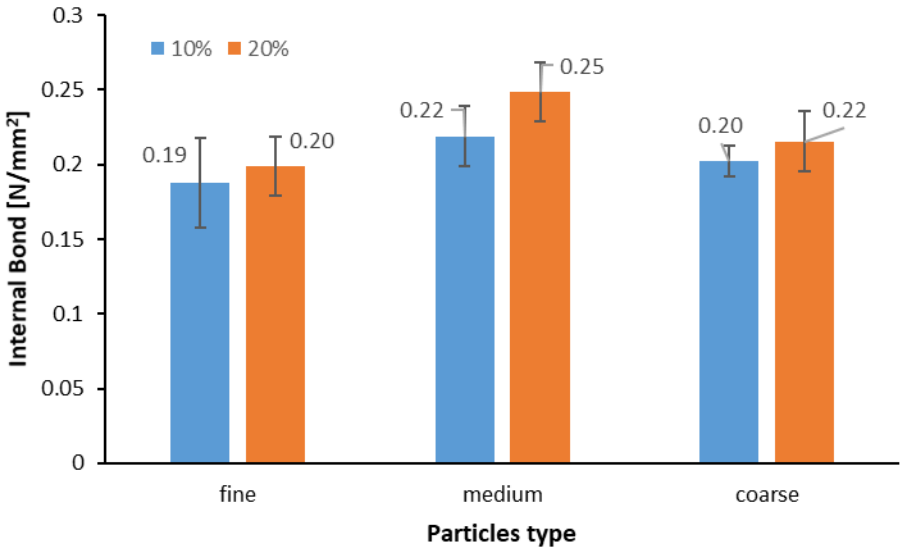

Figure 5. Internal Bond (IB) of the examined samples

Screw Withdrawal Resistance

In figure 6 SWR of the examined panels has been shown. The highest SWR values were obtained for particleboards with a coarse particle and the resination of 20%, equaling 19.7 N/mm^2. For the same type of particle, but with a resination value of 10%, the SWR value was 17.3 N/mm^2. The medium-particle particleboards exhibited an SWR of 12.4 N/mm^2 for a resination of 20% and 10.9 N/mm^2 for a resination of 10%. The fine-particle boards had SWRs of 9.9 N/mm^2 and 9.4 N/mm^2 for resination of 20% and 10%, respectively. The statistically significant differences in mean SWR value among the same resination have been found for all tested panels. When analyzing the mean SWR among the particle type, the statistically significant differences in mean SWR value have been found only for coarse particle samples.

Water Absorption and Thickness Swelling

In figure 7 the results of the examination of WA have been illustrated. All panel variants were tested after two hours and after one day of soaking in water. The highest water absorption was observed in the case of particleboards with fine particles. The boards with the resination equal to 10% obtained WA values of 193.0% after 2 h and 211.6% after 24 h of soaking. In the case of boards with a resination equal to 20%, the WA was 185.4% and 189.3%, after 2h and 24h of soaking, respectively. The second highest WA showed particleboards with medium particle size. For boards of this size of particles and the resination equal to 10%, the obtained values were 152.5% after 2 hours of soaking and 178.8% after the day of soaking. For boards with 20% bonding, these values were 127.9% for 2 h of soaking and 139.4% for 24 h of soaking in water. In the case of coarse-particle boards, water absorption was the lowest and for boards with 10% resination WA it was 137.8% after 2 hours and 159.7% after 24 hours of soaking. As for this variant of the particle thickness with the resination equal to 20%, after 2 hours of soaking in water, WA was 110.8%, and after 24 hours - 117.5%. The statistically significant differences in mean WA value among the same resination have been found for all tested particle type panels, for both, 2h and 24 of soaking. When analyzing the mean WA among the particle type, statistically significant differences in mean WA value have been found for all tested particle type panels, for both, 2h and 24 of soaking. When analyzing the mean WA among the soaking time, statistically significant differences have been found for 10% resination only, in the case of all tested types of particles.

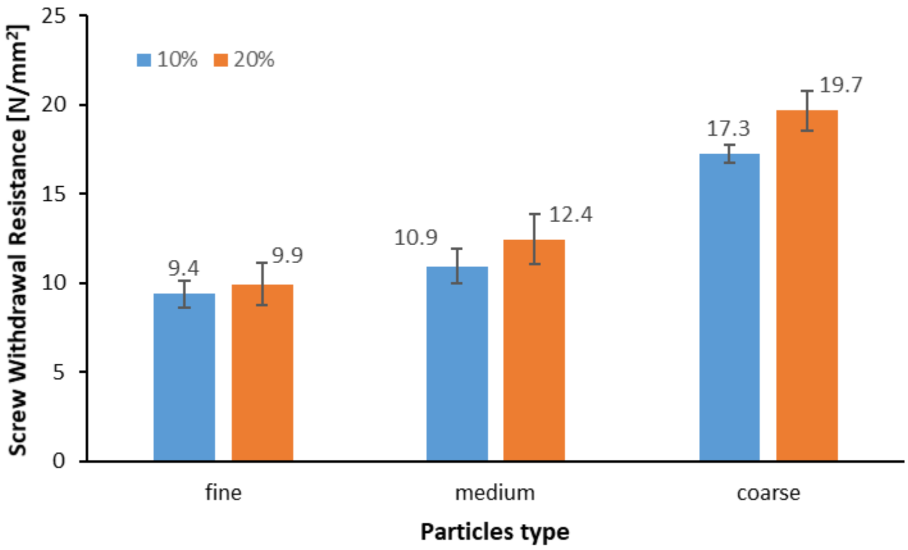

Figure 6. Screw Withdrawal Resistance (SWR) of the examined samples

In figure 8 the results of the examination of thickness swelling of the panels produced have been shown. For particleboards with fine particles and the resination equal to 10%, TS was 93.3% after 2 hours of soaking and 100.4% after 24 hours of soaking. For boards with the same particle size but the resination equal to 20%, TS after 2 hours of soaking was 69.2%, and after 24 hours - 75.0%. In the case of medium-particle particleboards, after 2 hours of soaking TS was 87.7% for 10% bonding and 75.6% for 20% bonding. After 24 hours, these values were 102.8% and 78.6% for 10% and 20% resination, respectively. As for the samples with the coarse particle, for the resination of 10%, the TS was 77.2% after 2 hours of soaking and 88.5% after 24 hours of soaking. For the variant with the resination of 20%, the TS after 2 h was 67.0%, and after one day it was 78.9%. The statistically significant differences in mean TS value among the same resination have been found for fine and coarse particles type panels, for both, 2h and 24 of soaking. When analyzing the mean TS among the particle type, statistically significant differences in mean TS value but different resination have been found for fine and medium particle type panels, for both, 2h and 24 of soaking. When analyzing the mean TS among the soaking time, statistically significant differences have been found for 10% of resination panels made of medium particles, 10% of resination panels made of coarse particles, as well as for 20% of resination panels made of fine and coarse particles.

As proved by PAPADOPOULOS *et al*. (2002), the increase in resin content in one-layer particleboard resulted not only in increasing mechanical properties of the panels but also in decreasing TS values, which corresponds with the results obtained in this study. Also, PAN *et al.* (2007) confirmed, that increasing the resination in particleboards bonded with UF resin, caused improvement in WA and TS results by decreasing percentage values in both parameters.

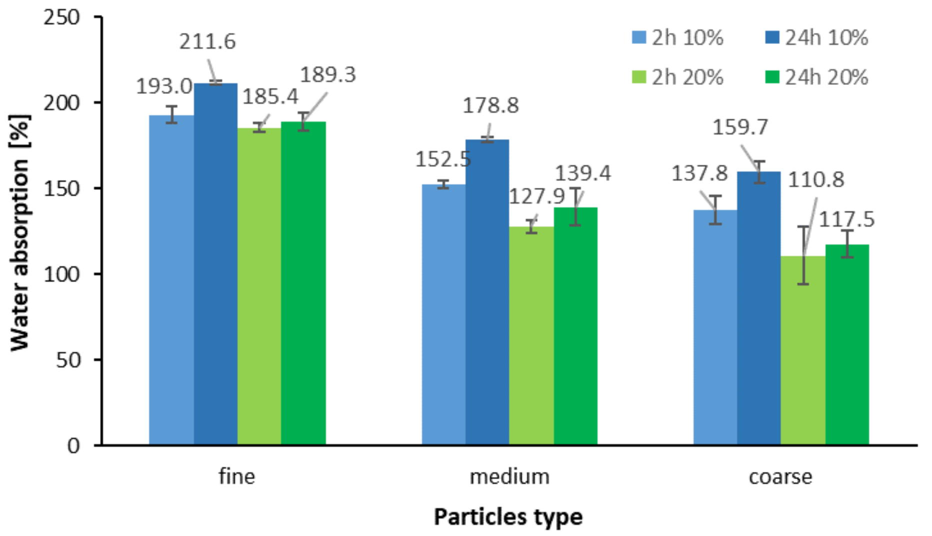

Figure 7. Water absorption (WA) of the examined samples

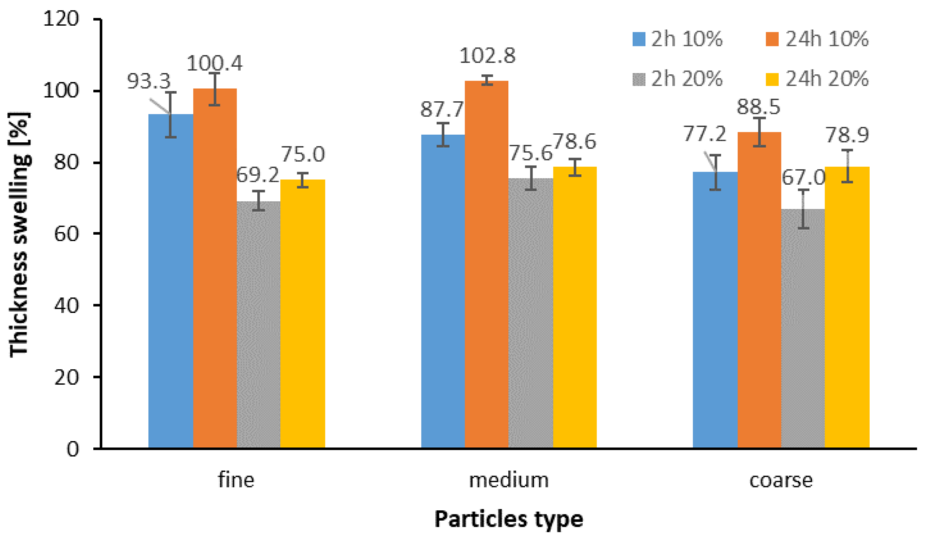

Figure 8. Thickness swelling (TS) of the examined panels

RIZHIKOVS *et al*. (2019) investigated particleboards bonded with suberinic acids. The boards were made of birch shavings, while the resination was 20%. The plates were pressed at a temperature of 220ºC. The boards had a nominal density of 800 kg/m^3. The research showed that the TS after 24 hours of soaking such a plate was about 23.3%, which is much less than in the present study. MOE was 1645 N/mm^2, while MOR was 8.7 N/mm^2. The modulus of elasticity in our study for coarse-particle boards was more than 2000 N/mm^2, however, the MOE values in the results obtained by Rizhikovs exceeded ours. IB in his studies equaled 1.2 N/mm^2. However, attention should be paid to the higher density of the plates he tested, a different pressing temperature, and the fact that in our research we used post-extraction bark.

RIZHIKOVS *et al*. (2022) examined the physical and mechanical properties of P3 standard particleboards, in accordance with the EN312 standard. The density of the tested boards was 850 kg/m^3. TS after 24 h of soaking in water was below 17%, MOR above 15 N/mm^2, MOE above 2050 N/mm^2, and IB - above 0.45 N/mm^2. Here, the binder was also extracted birch bark with suberinic acid as the main ingredient.

The study conducted by FERREIRA *et* al (2019) intended to study the particleboards bonded using a low-cost natural binder based on the association of thick spent sulfite liquor (a byproduct of the wood pulping process) with wheat flour. Particleboards were produced with densities ranging from 682 kg/m^3 to 783 kg/m^3, temperatures from 180 to 210 °C, and pressing times between 8 to 10 min, all samples were prepared in accordance with the requirements of standard EN 312 for particleboards type P2. By the density of 700 kg/m^3, so equaling densities introduced in this paper, IB was about 0.5 N/mm^2, ranging at values higher than obtained in our study.

SANTOSO *et al.* (2019) examined particleboards produced at 180ºC pressed temperature and 10 % of resin content with nipa fronts as the binder. It showed that the value of TS is 2.4 %, the WA is 41 %, internal IB at 0.2 N/mm^2, modulus of rupture (MOR) at 5.5 N/mm^2, and modulus of elasticity (MOE) at 1600 N/mm^2. The results showed that MOR and MOE were still not meeting the standards of JIS A 5908: 2003. The most optimum particleboards in this research were citric acid bonded particleboards with hot water extraction which produces particleboard with characteristics: density 840 kg/m^3, TS 1.12 %, WA 21.83 %, IB 0.49 N/mm^2, MOR 10.42 N/mm^2, and MOE 3650 N/mm^2. All of the properties meet the requirements of the JIS A 5908: 2003 standard.

The particleboards examined in this study meet the requirements set by the EN312 standard for P2 – type panels only in case of modulus of elasticity for panels made of coarse particles.

CONCLUSIONS

Results of the conducted studies allowed to formulate the following conclusions:

- Thickness swelling and water absorption decrease with higher resination.
- The higher particle resination causes smaller differences in thickness swelling and water absorption between 2h and 24h of soaking time.
- The higher particle size and resination, the higher screw withdrawal resistance.
- By medium-sized particles, the internal bond showed the highest values, and the internal bond increased by increasing resination.
- The higher the particle size and resination, the higher modulus of elasticity values.
- The highest modulus of rupture values was obtained by medium-particle samples and 20% resination.

- Particleboards bonded with residues from bark extraction meet the EN312:2010 standard requirements for P2 – type panels only in case of modulus of elasticity for panels made of coarse particles.

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Author contributions: Aleksandra Jeżo – state-of-art, formal analysis, investigation, data curation, writing - original draft, writing - review & editing; **Anita Wronka** – conceptualization, methodology, validation, formal analysis, investigation, writing - review & editing, funding acquisition.

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Streszczenie: *Pozostałości poekstrakcyjne kory brzozy jako potencjalne spoiwo w płytach wiórowych*. W dzisiejszych czasach w branży kompozytów drewnopochodnych bardzo ważną rolę odgrywają takie aspekty jak ekologia i prowadzenie gospodarki o obiegu zamkniętym. Jednak bardzo ważne jest również bezpieczeństwo użytkownika. Formaldehyd jest jedną z niebezpiecznych substancji, która emitowana w zbyt dużej ilości może zaszkodzić zdrowiu ludzkiemu. Niestety, w przemyśle płyt drewnopochodnych nadal dominują spoiwa wytwarzane na bazie formaldehydu. Dlatego niniejszy artykuł dotyczy możliwości wykorzystania pozostałości poekstrakcyjnych uzyskanych podczas ekstrakcji kwasu suberynowego jako bezformaldehydowego i ekologicznego spoiwa w produkcji płyt wiórowych. Główny składnik, kwas suberynowy, to bezbarwne, krystaliczne ciało stałe wykorzystywane w syntezie leków i produkcji tworzyw sztucznych. Celem przeprowadzonych badań była odpowiedź na pytanie: skoro sam kwas suberynowy jest dobrym spoiwem w produkcji płyt wiórowych, jak opisano w innych publikacjach, to czy pozostałości poekstrakcyjne również mają podobnie dobre właściwości łączenia cząstek w płytach wiórowych, w zależności od wielkości wióra? Dodatkowo wykorzystanie pozostałości poekstrakcyjnych kory, a co za tym idzie eliminacja klejów syntetycznych w procesie produkcyjnym tworzyw drzewnych, pozwoliłoby na ponowne wykorzystanie surowca drzewnego, co doskonale wpisuje się w ideę upcyclingu. Badania wykazały, że wykorzystując pozostałości poekstrakcyjne kory brzozy, stosując zaklejenie 10% i 20%, wymagania normy EN312:2010 zostały spełnione jedynie w przypadku modułu sprężystości na zginanie dla płyt wytworzonych z największych cząstek drzewnych stosowanych w badaniach. Na poprawę właściwości badanych płyt wpływał stopień zaklejenia oraz wielkość cząstek drzewnych (wiórów).

Słowa kluczowe: płyta wiórowa, klej, spoiwo, formaldehyd, UF, kora, upcykling

Corresponding author:

Anita Wronka
Nowoursynowska Str. 159
02-787 Warsaw, Poland
email: anita_wronka@sggw.edu.pl