Science paper
Artykuł naukowy

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www.biuletyn.online

Biuletyn Informacyjny OB-RPPD 3-4 (2224) 107-118
https://doi.org/10.32086/biuletyn.2224.03

www.obrppd.com.pl

Low density particleboards with the addition of expanded rice

Płyty wiórowe lekkie z dodatkiem ryżu ekspandowanego

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Abstract

Low-density particleboards are one of the directions of development of traditional particleboards. One of the methods of reducing the density of standard particleboards is to combine traditional wood raw material with other materials. The aim of this study was to determine the effect of the addition of expanded rice particles on selected physical and mechanical properties of 3-layer low-density particleboards. The scope of work included the production of boards with 10%, 15% and 20% rice content in the inner layer and a reference board (without rice addition). For the produced particleboards, the density, density profile, MOR, MOE, IB, as well as swelling in thickness and water absorption 2 h and 24 h after soaking in water were determined.

The conducted tests allowed to conclude that expanded rice can be used as a filler for the core layer of lightweight particleboards, while the share of expanded rice above 10% causes a decrease in mechanical properties. In addition, the increase in the share of expanded rice in the core layer of particleboards increases their water absorption and swelling after soaking in water. Boards with its addition are not suitable for use in conditions of increased humidity.

Streszczenie

Płyty wiórowe o obniżonej gęstości stanowią jeden z kierunków rozwoju tradycyjnych płyt wiórowych. Jednym ze sposobów obniżenia gęstości standardowych płyt wiórowych jest łączenie tradycyjnego surowca drzewnego z innymi materiałami. Celem niniejszego opracowania było określenie wpływu dodatku cząstek ryżu ekspandowanego na wybrane właściwości fizyczne i mechaniczne 3-warstwowych płyt wiórowych o obniżonej gęstości.

Zakres pracy obejmował wytworzenie płyt z 10%, 15% i 20% udziałem ryżu w warstwie wewnętrznej oraz płyty referencyjnej (bez dodatku ryżu). Dla wytworzonych płyt wiórowych oznaczono gęstość, profil gęstości, MOR, MOE, IB, oraz spęcznienie na grubość i nasiąkliwość 2 h i 24 h po moczeniu w wodzie.

Przeprowadzone badania pozwoliły stwierdzić, że ekspandowany ryż może być stosowany jako wypełniacz do warstwy środkowej płyt wiórowych lekkich, przy czym udział ekspandowanego ryżu powyżej 10% powoduje obniżenie właściwości mechanicznych. Ponadto wzrost udziału ryżu ekspandowanego w środkowej warstwie płyt wiórowych zwiększa ich nasiąkliwość i spęcznienie po moczeniu w wodzie. Płyty z jego dodatkiem nie nadają się do użytkowania w warunkach podwyższonej wilgotności.

Keywords: lightweight particleboards, expanded rice, mechanical properties, physical properties

Słowa kluczowe: płyty wiórowe lekkie, ryż ekspandowany, właściwości mechaniczne, właściwości fizyczne

Introduction

Low-density particleboards are wood-based materials designed to be lightweight while retaining basic mechanical properties. Various species of low-density wood, such as poplar, pine or paulownia (Boruszewski et al. 2016, Röllig et al. 2024), as well as agricultural residues, such as rapeseed straw or sunflower stalks (Dziurka et al. 2015, Taghiyari et al. 2017), are used for their production. It is also possible to combine different raw materials in one board in the core layer and face layers, which allows for optimizing the strength and density of materials (Boruszewski et al. 2016, Taghiyari et al. 2017). Röllig et al. (2024) also drew attention to the possibility of using high-frequency pressing technology to produce low-density boards. In addition to lignocellulosic raw materials, foamed raw materials such as expanded polystyrene (EPS) introduced into the core layer of the material are also used to improve the integrity and mechanical properties of low-density particleboards and reduce their production costs (Luo et al. 2020). Kharazipour and Bohn (2007) and Czechowska et al. (2010) proposed the use of popcorn as a filler for lightweight particleboards.

With regard to the properties of chipboards, it should be stated that materials with higher density generally have better mechanical properties, such as modulus of rupture and modulus of elasticity (Boruszewski et al. 2016, Röllig et al. 2024). Decreasing density often leads to deterioration of mechanical properties, which requires careful selection of raw materials and production process parameters (Luo et al. 2020, Lengyel et al. 2018). Monteiro et al. (2016) produced boards glued with foamed cassava starch, which at a density of 318 kg/m^3 were characterized by an IB value of 0.67 N/mm^2 and a thickness swelling of 8.7%. Xu et al. (2004) produced boards with a kenaf core layer which, at a density of 200 kg/m^3, were characterized by MOR values of 1.1 N/mm^2, MOE values of 300 N/mm^2 and thickness swelling of 6.6%. Additionally, these boards were characterized by thermal conductivity at the level of mineral wool and a high sound absorption coefficient, which makes them suitable for insulation purposes (Xu et al. 2004). A similar effect was obtained by Faustino et al. (2012) by producing particleboards from corn cobs. In subsequent studies, it was shown that the addition of raw materials such as EPS or shredded sunflower stalks can improve the internal bond values of the boards and reduce their swelling in thickness, although this may require optimization of the sizing degree and pressing conditions (Dziurka et al. 2015, Taghiyari et al. 2017, Luo et al. 2020, Shupin et al. 2020, Regmi et al. 2022).

Low-density particleboards, regardless of their manufacturing method, can achieve a balance between mechanical strength, dimensional stability, and acoustic and thermal insulation properties, making them suitable for various applications in the construction and furniture industries (Monteiro et al. 2016, Xu et al. 2004, Luo et al. 2020, Faustino et al. 2012, Özlüsoylu 2023, Monteiro et al. 2020, Regmi et al. 2022). This is also confirmed by the industrial production of Kaurit® Light light particleboards containing expanded polystyrene particles in their structure (https://www.drewno.pl). It is worth noting that currently solutions based on natural raw materials are particularly desirable. In this context, research was undertaken on the possibility of using expanded rice as a filler for light particleboards.

Aim and scope of work

The aim of the work was to investigate the effect of the addition of expanded rice particles on selected physical and mechanical properties of 3-layer particleboards with reduced density. The scope of the work included the production of boards with 10%, 15% and 20% rice content in the inner layer and a reference board (without rice addition). The produced boards were tested for selected mechanical properties (static bending strength, modulus of elasticity, tensile strength perpendicular to the board plane) and physical properties (density and density profile, swelling and water absorption after 2 h and 24 h of soaking in water).

Materials and Methods

Industrial pine particles were used to produce the particleboards. The moisture content of the wood particles for the face layers was 5.5%, and for the core layer it was 7.5%. The difference in moisture content of the particles in the individual layers of the board results from the need to ensure proper heat transfer during pressing. Puffed rice (P.P. „Prepar" Józef Sidor, Chojnice, Poland) with a moisture content of 9% was used as an additive. Puffed rice is produced by the action of steam on rice grains in a high temperature environment. The water contained in the grains is quickly heated, which leads to their expansion.

Three-layer particleboards with a thickness of 15 mm and a density of 550 kg/m³ were made in four variants: a control board with no puffed rice, and three boards in which puffed rice constituted 10%, 15%, and 20% of the mass of the middle layer. The share of the outer layers was 35%. The whole was glued using urea-formaldehyde resin UF. The degree of gluing of the outer layers was 12%, and of the middle layer 8%. A 10% aqueous solution of ammonium sulphate was used as a hardener. The gluing of raw materials was carried out in a mixer with pneumatic spraying. The formation of the mats was carried out manually in accordance with the adopted variants (Fig. 1).

Fig. 1. Example of the core layer of a formed matt
Rys. 1. Przykładowa warstwa wewnętrzna formowanego kobierca

The pressing process was carried out in a single-plate press at a maximum unit pressure of 2.5 MPa. The pressing time was 270 s, and the pressing temperature was 200°C. The produced boards were conditioned for 7 days in laboratory conditions (20±2 °C, 65±5% relative air humidity).

The following were determined as part of the tests:

- Density based on PN-EN 323:1999;
- Density profile using GreCon Da-X (Alfeld, Germany). Samples measuring 50×50 mm^2 were analyzed with a 0.02 mm increment at a measuring speed of 0.05 mm/s;
- Modulus of rapture and modulus of elasticity in static bending based on PN-EN 310:1994;
- Tensile strength in the direction perpendicular to the planes of the board based on PN-EN 319:1999;
- Thickness swelling and water absorption after 2 and 24 hours of soaking in water were determined based on the assumptions of PN-EN 317:1999.

Each of the conducted determinations was performed in 10 repetitions for each variant of the manufactured particleboards. Statistical analysis of the obtained results was performed in the Statistica13 program. The analysis used one-way ANOVA analysis of variance. In order to compare the significance of differences in the mean values of the studied features for individual variants, homogeneous groups were used based on the Tukey test.

Results and Discussion

The average densities for individual variants of the manufactured particleboards are presented in Fig. 2. Regardless of the variant manufactured, all board densities were close to the assumed average density of 550 kg/m^3 and belong to the same homogeneous group (Fig. 2). Analyzing the one-way analysis of variance (Table 1), it can be stated that the addition of expanded rice affected the density value of the boards only by 1.0%. In this case, the influence of factors not analyzed in the study was decisive (Error = 99.0%).

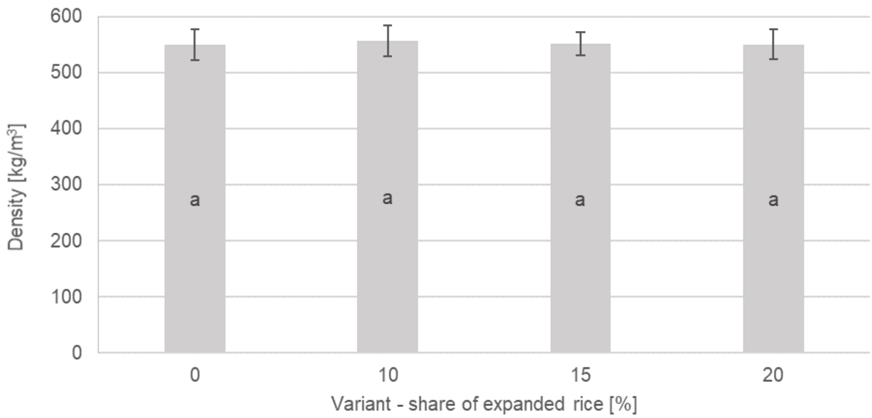

Fig. 2. Average densities of the produced particleboards; a - homogeneous group based on the Tukey test
Rys. 2. Średnie gęstości wytworzonych płyt wiórowych; a - grupa jednorodna w oparciu o test Tukeya

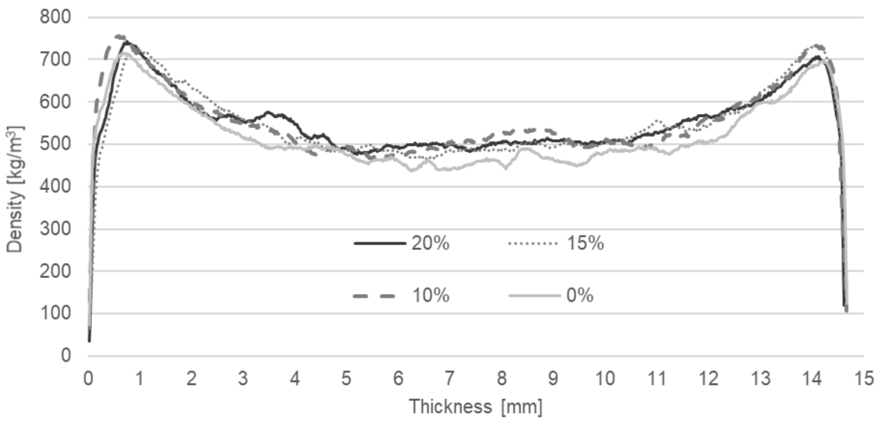

Fig. 3. Density profiles of manufactured particleboards
Rys. 3. Profile gęstości wytworzonych płyt wiórowych

Analyzing the density profiles presented in Fig. 3, it can be concluded that in all cases the density distribution is similar and is typical for this type of formation - U-shaped diagram (Thoemen et al. 2010). It is worth noting that the particleboards made entirely of industrial wood particles - variant 0%, are characterized by a relatively least even density profile and a slightly lower density of the inner layer. This may indicate a slightly higher porosity of the middle layer in the case of the control boards.

The results of the MOR and MOE determination of the tested boards are presented in Fig. 4 and 5. Analyzing the results, it can be generally stated that the addition of rice to the core layer of the board in an amount exceeding 10% reduces its MOR and MOE. The recorded decrease in the values of the tested features is statistically significant - different homogeneous groups. It is worth noting that according to the EN 16368 standard, low density LP2 particleboard with a thickness of 13-20 mm should be characterized by MOR values of at least 7 N/mm^2 and MOE values of at least 950 N/mm^2.

The decrease in MOR and MOE values is probably caused by different dimensional characteristics of particles and expanded rice particles. Partial replacement of wood particles with rice particles could have influenced differences in the process of sizing particles and their mutual connection. The above-mentioned factors determined the insufficient cohesion of rice particles, which in effect contributed to the decrease in MOR and MOE values compared to the control variant.

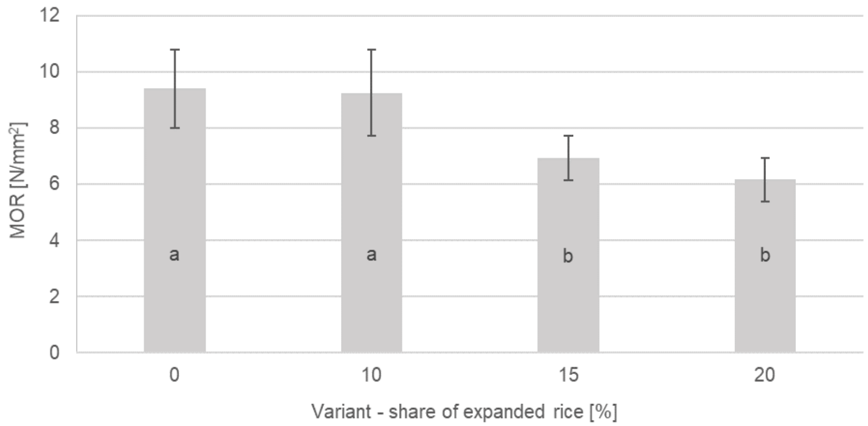

Fig. 4. MOR study results; a, b - homogeneous groups based on Tukey’s test
Rys. 4. Wyniki badania MOR; a, b - grupy jednorodne w oparciu o test Tukeya

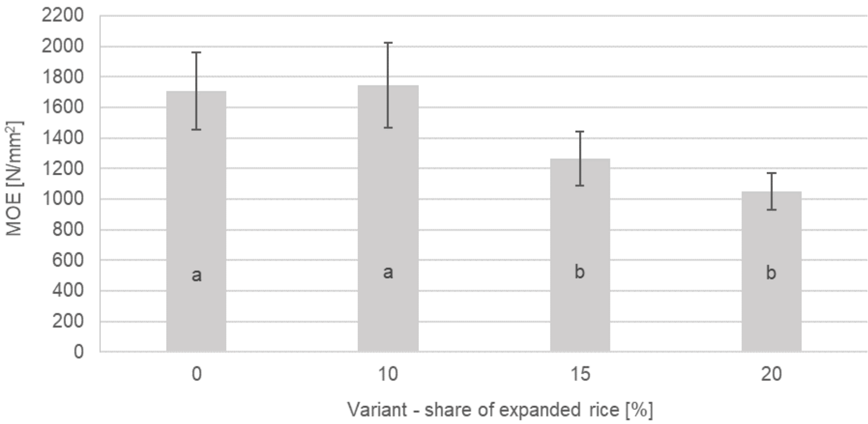

Fig. 5. Results of the MOE study; a, b - homogeneous groups based on Tukey's test
Rys. 5. Wyniki badania MOE; a, b - grupy jednorodne w oparciu o test Tukeya

Analyzing the one-way analysis of variance (Table 1), it can be concluded that the addition of expanded rice played a decisive role in the MOR and MOE values, accounting for 61.9% and 67.4% of the impact, respectively. In turn, the impact of factors not analyzed in the study (Error) was 38.1% and 32.6%, respectively.

The IB test results are presented in Fig. 6. Based on the obtained results, it can be stated that the addition of rice to the core layer of the board increases its IB values. It should be added, however, that the obtained differences in IB values between the individual variants, although visible, are statistically insignificant (the same homogeneous group). It is also worth emphasizing that all the boards produced meet the requirements of the EN 16368 standard - low density particleboards LP2 with a thickness of 13-20 mm should be characterized by IB values of at least 0.35 N/mm^2. Similar trend of increasing IB values was also shown by Shupin et al. (2020) who studied low density boards with the addition of expanded polystyrene in the middle layer. The authors also obtained higher strength of boards with the addition of expanded polystyrene compared to the control boards - made only from wood particles.

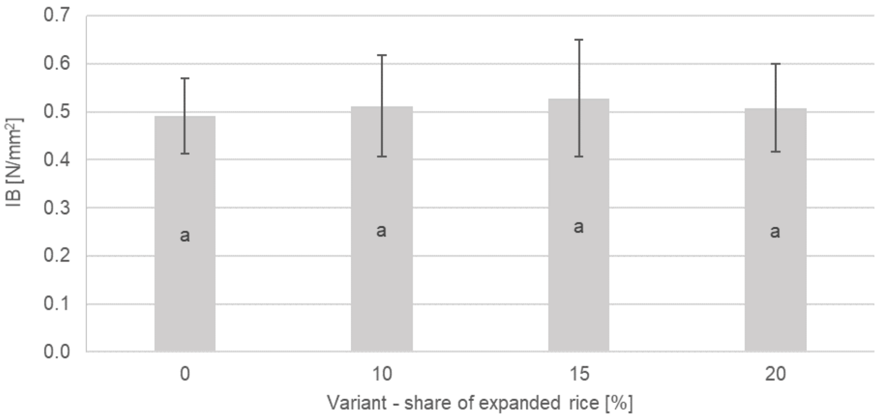

Fig. 6. Results of the IB test; a - homogeneous group based on Tukey's test
Rys. 6. Wyniki badania IB; a - grupa jednorodna w oparciu o test Tukeya

Analyzing the one-way analysis of variance (Table 1), it can be stated that the addition of expanded rice affected only 1.9% of the IB value of the produced boards. In this case, the decisive factor was the influence of factors not analyzed in the study (Error = 98.1%).

Table 1. Analysis of variances results of mechanical properties of particleboards
Tabela 1. Analiza wariancji wyników właściwości mechanicznych płyt wiórowych

Factor	Density		MOR		MOE		IB	
	p	X	p	X	p	X	p	X
Share of expanded rice	0.711	1.0	0.000	61.9	0.000	67.4	0.876	1.9
Error		99.0		38.1		32.6		98.1

p - significant with α=0.05; X - percentage of contribution

The results of the determination of the thickness swelling and water absorption are presented in Fig. 7 and 8. In the case of both thickness swelling and water absorption, the increase in the expanded rice content influenced the increase in the values of the tested features (deterioration of the board properties). All the observed differences were statistically significant (different homogeneous groups).

It is worth emphasizing that all boards after 2 h of soaking (regardless of the variant) reached almost 90% of the final swelling and almost 95% of the final water absorption obtained after 24 h of soaking. The increase in TS and WA values is probably due to the weaker bonding of expanded rice particles with wood chips, and consequently, easier water penetration into the board structure.

In addition, it should be added that expanded rice is not a water-resistant raw material. Analyzing the one-way analysis of variance (Table 2), it can be stated that the addition of expanded rice affected the TS value of the produced boards by 90.0% (after 2 h) and 88.5% (after 24 h). The influence of factors not analyzed in the study (Error) was only 10.0%

and 11.5%, respectively. In the case of WA, the addition of expanded rice affected by over 61.7% (after 2 h) and 62.6% (after 24 h), while the influence of factors not analyzed in the study (Error) was 38.3% and 37.4%, respectively.

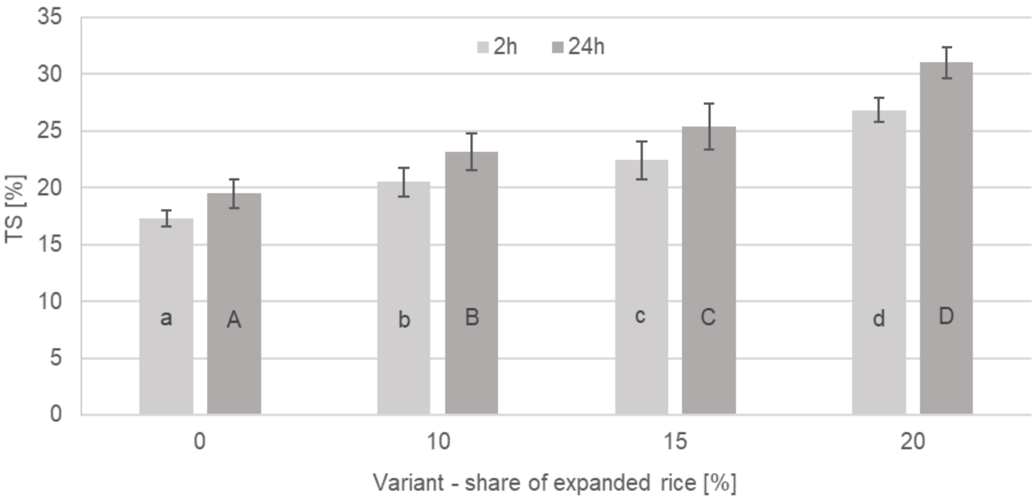

Fig. 7. Thickness swelling test results; a, b, c, d, A, B, C, D - homogeneous groups based on Tukey's test
Rys. 7. Wyniki badania TS; a, b, c, d, A, B, C, D - grupy jednorodne w oparciu o test Tukeya

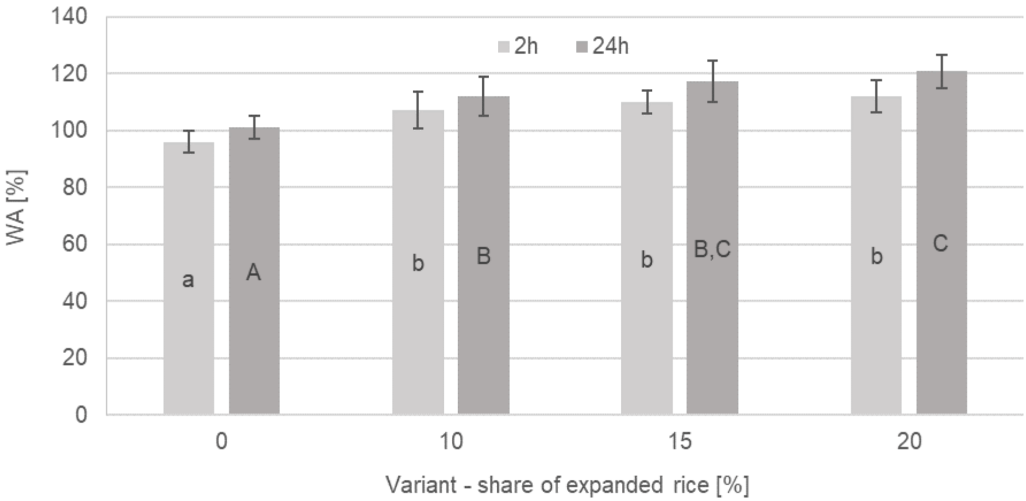

Fig. 8. Water absorption test results; a, b, A, B, C - homogeneous groups based on Tukey's test
Rys. 8. Wyniki badania WA; a, b, A, B, C - grupy jednorodne w oparciu o test Tukeya

Table 2. Analysis of variances results of physical properties of particleboards
Tabela 2. Analiza wariancji wyników właściwości fizycznych płyt wiórowych

Factor	Thickness swelling				Water absorption			
	2 h		24 h		2 h		24 h	
	p	X	p	X	p	X	p	X
Share of expanded rice	0.000	90.0	0.000	88.5	0.000	61.7	0.000	62.6
Error		10.0		11.5		38.3		37.4

p - significant with α=0.05; X - percentage of contribution

Conclusions

Based on the tests of lightweight particleboards with the addition of expanded rice in the middle layer, the following conclusions can be drawn:

1. Expanded rice can be used as a filler for the core layer of lightweight particleboards, but its addition should not exceed 10%;
2. The addition of expanded rice above 10% to the core layer of lightweight particleboards reduces the static bending strength and the modulus of elasticity in static bending;
3. The addition of expanded rice to the core layer of lightweight particleboards in an amount of up to 20% does not statistically significantly affect the perpendicular tensile strength of the boards;
4. The increase in the share of expanded rice in the core layer of lightweight particleboards increases its water absorption and thickness swelling after soaking in water. Boards with its addition are not suitable for use in conditions of increased humidity.
5. The addition of expanded rice to the core layer of lightweight particleboards in an amount of up to 20% does not affect the course of the board density profiles.

References

Boruszewski P., Borysiuk P., Maminski M., Czechowska J., 2016: Mat compression measurements during low-density particleboard manufacturing. BioResources 11(3), 6909-6919, DOI: 10.15376/biores.11.3.6909-6919

Czechowska J., Zbieć M., Borysiuk P., 2010: Popcorn-modified particleboards. Part 1 Mechanical properties. 7th International Science Conference: „Chip and Chipless Woodworking Processes", Zborník referátov, Hotel Boboty, Terchová, 9-11 September 2010, 219-223

Dziurka D., Mirski R., Dukarska D., Derkowski A., 2015: Possibility of using the expanded polystyrene and rape straw to the manufacture of lightweight particleboards. Maderas: Ciencia y Tecnologia, 17(3): 647 - 656, DOI:10.4067/S0718-221X2015005000057

Faustino J., Pereira L., Soares S., Cruz D., Paiva A., Varum H., Ferreira J.V., Pinto J., 2012: Impact sound insulation technique using corn cob particleboard. Construction and Building Materials, 37:153-159, DOI: 10.1016/j.conbuildmat.2012.07.064

Kharazipour A., Bohn C., 2007: Use of popcorn for timber and composite materials. United States Patent, US 8,568,895 B2

Lengyel K., Barbu M.C., Campean M., Bogdan B., 2018: Improving properties of particleboards with reduced density. BioResources, 13(1):1289-1302, DOI: 10.15376/biores.13.1.1289-1302

Luo S., Gao L., Guo W., 2020: Effect of expanded polystyrene content and press temperature on the properties of low-density wood particleboard. Maderas: Ciencia y Tecnologia, 22(4): 549 - 558, DOI: 10.4067/S0718-221X2020005000413

Luo S., Gao L., Guo W., 2020: Effect of face layer manipulation on the density profile and properties of low density particleboard. Wood Research, 65(1):125-134, DOI: 10.37763/wr.1336-4561/65.1.125134

Monteiro S., Martins J., Magalhães F.D., Carvalho L., 2016: Low density wood-based particleboards bonded with foamable sour cassava starch: Preliminary studies. Polymers, 8(10): 354, DOI: 10.3390/polym8100354

Monteiro S., Nunes L., Martins J., Magalhães F.D., Carvalho L., 2020: Low-density cardoon (*Cynara cardunculus L.*) particleboards bound with potato starch-based adhesive. Polymers, 12(8):1799, DOI: 10.3390/polym12081799

Özlüsoylu İ, 2023: The Effect of Varnish Type, Glue Amount, and Density on the Surface Properties of Low Density Particleboards Produced From Waste Wood Bark. BioResources, 18(4):7025-7040, DOI: 10.15376/biores.18.4.7025-7040

Regmi S., Bajwa D., Igathinathane C., Nahar N., 2022: High fiber fraction DDGS - A functional filler for manufacturing low-density particleboards. Industrial Crops and Products, 181:114793, DOI: 10.1016/j.indcrop.2022.114793

Röllig P., Tudor E.M., Barbu M.C., Direske M., 2024: Effect of the particle geometry on lightweight particleboard from Paulownia using high-frequency pressing technology. Wood Material Science and Engineering, 19(3), 683-690, DOI: 10.1080/17480272.2023.2286625

Shupin L., Li G., Wenjing G., 2020, Effect of expanded polystyrene content and press temperature on the properties of low-density wood particleboard. Maderas. Ciencia y tecnología, 22(4): 549-558, DOI: 10.4067/S0718-221X2020005000413

Taghiyari H.R., Taheri A., Omrani P., 2017: Correlation between acoustic and physical-mechanical properties of insulating composite boards made from sunflower stalk and wood chips. European Journal of Wood and Wood Products, 75(3): 409-418, DOI: 10.1007/s00107-016-1101-7

Thoemen H., Irle M., Sernek M., 2010: Wood-based panels. An introduction for specialists. Brunel University Press.

Xu J., Sugawara R., Widyorini R., Guangping H., Kawai S., 2004: Manufacture and properties of low-density binderless particleboard from kenaf core. Journal of Wood Science, 50(1):62-67, DOI: 10.1007/s10086-003-0522-1

Internet sources

https://www.drewno.pl/artykuly/7066,kauritr-light-lekkie-plyty-wiorowe-w-nowej-technologii.htm

List of standards

PN-EN 317:1999 Płyty wiórowe i płyty pilśniowe - Oznaczanie spęcznienia na grubość po moczeniu w wodzie

PN-EN 319:1999 Płyty wiórowe i płyty pilśniowe - Oznaczanie wytrzymałości na rozciąganie w kierunku prostopadłym do płaszczyzn płyty

PN-EN 323:1999 Płyty drewnopochodne - Oznaczanie gęstości

PN-EN 310:1994 Płyty drewnopochodne - Oznaczanie modułu sprężystości przy zginaniu i wytrzymałości na zginanie

EN 16368 Lightweight Particleboards - Specifications

Reviewed paper / Artykuł recenzowany

Submitted / Zgłoszony: 06.11.2024

Published online / Opublikowany online: 08.01.2025