Science paper
Artykuł naukowy

Available online at / Dostępny na stronie
www.biuletyn.online

Biuletyn Informacyjny OB-RPPD 1-2 (2021) 5-11
https://doi.org/10.32086/biuletyn.2021.01

www.obrppd.com.pl

Evaluation of the physical and mechanical properties of particle boards manufactured containing plum pruning waste

Wpływ udziału drewna śliwy na właściwości wytwarzanych płyt wiórowych

Radosław Auriga[a,*], *ORCID: 0000-0001-5627-2425*
Piotr Borysiuk[b], *ORCID: 0000-0002-7508-9359*
Zuzanna Misiura[a],

[a]*Szkoła Główna Gospodarstwa Wiejskiego w Warszawie, Instytut Nauki Drzewnych i Meblarstwa, Katedra Mechanicznej Obróbki Drewna, ul. Nowoursynowska 159, 02-787 Warszawa, Polska*

[b]*Szkoła Główna Gospodarstwa Wiejskiego w Warszawie, Instytut Nauki Drzewnych i Meblarstwa, Katedra Technologii i Przedsiębiorczości w Przemyśle Drzewnym, ul. Nowoursynowska 159, 02-787 Warszawa, Polska*

[*]*Corresponding author: radoslaw_auriga@sggw.edu.pl*

Abstract

The experiment involved manufacturing three-layer particleboards with the addition of plum wood (25% and 50%) originating from the annual maintenance pruning. The reference board was made of an industrial softwood blend. Mechanical (MOR, MOE, IB) and physical properties (thickness swelling after 2 h and 24 h immersion in water, and water absorbance) of the boards were assessed. It was found that the share of plum pruning waste significantly decreased the strength properties and increased the thickness swelling of the manufactured particleboards. Nevertheless, the boards met requirements of the EN 312: 2011 standard for P2 - boards for interior fitments (including furniture) for use in dry conditions.

Streszczenie

W ramach pracy zbadano wpływ udziału drewna śliwy pochodzącego z rocznego cięcia pielęgnacyjnego na właściwości mechaniczne i fizyczne wytwarzanych płyt wiórowych. Wytworzono trójwarstwowe płyty wiórowe z 0%, 25% i 50% udziałem wiórów z odpadowego drewna śliwy. Wytworzone płyty wiórowe zbadano pod kątem właściwości mechanicznych (MOR, MOE, IB) i fizycznych (spęcznienie na grubość po 2 h i 24 h moczenia w wodzie). Stwierdzono że udział wiórów z odpadowego drewna śliwy wpływa na istotny statystycznie spadek właściwości wytrzymałościowych płyt. Przy czym płyty z udziałem drewna śliwy spełniają wymagania zawarte w normie EN 312:2011 dla płyt typu P1. Ponadto udział wiórów z drewna śliwy wpłyną generalnie na wzrost spęczniania na grubość wytwarzanych płyt wiórowych.

Keywords: plum wood, particleboard, waste wood, agricultural residue

Słowa kluczowe: drewno śliwy, płyty wiórowe, drewno odpadowe, biomasa rolnicza

Introduction

One of the most popular wood-based materials are particleboards. In 2019, its production volume came up to 45 million m^3 in Europe alone, and the world production, in the same year, reached 99.9 million m^3 (FAOSTAT). Such a high production value requires the availability of raw materials, which is limited on the market. Moreover, the growing demand for the feedstock engenders an increase in its price. All that enhance research on using alternative sources of raw material in the particleboards industry. Some valuable findings have been already reported by Warmbier et al. (2011) on willows (Salix vimnalis L.), Pawlak et al. (2018) on giant miscanthus (Miscanthus giganteus), Borysiuk and Laskowska (2009) grasses, and Auriga et al. (2019) on apple. Also, other attempts of utilization the residues of agricultural crops has been made, and included: corn cobs (Sekaluvu et al. 2014, Banjo Akinyemi et al. 2016), sunflower husk and bark (Klimek et al. 2016; Mahieu et al. 2021), hazelnut husk (Kowaluk and Kądziela 2014), grasses (Borysiuk and Laskowska 2009), bamboo (Suwan et al. 2020).

Fruit orchards and nurseries can be a significant potential source of lignocellulosic material. The area of fruit crops in Poland was 586 thousand hectars in 2019 (Rocznik statytyczny GUS 2019), and according to Gorzelany and Matłok (2013), Rabcewicz et al. (2007) the amount of lignocellulosic biomass from orchards ranges between 2.0 and 6.8 tons per hectare, depending on the plants age and agrotechnics applied. Klugmann-Radziemska (2015) estimated that the average wood residues produced after pruning in orchards amounted to 0.35 m^3 per hectare. The raw material in the form of branches is considered a waste of little use and is mainly burned (Dyjakon et al. 2016; Cichy et al. 2017).

Aim and scope of work

The study aimed to determine the influence of the plum tree pruning residues contribution on the mechanical and physical properties of the manufactured particleboards. As part of the work, particleboards with none-plum pruning content and boards with 25 and 50% of plum material were produced. The manufactured boards were tested for mechanical: MOR, MOE, IB, and physical: thickness swelling (TA), water absorption (WA) properties.

Materials and Methods

Raw material

For manufacturing the particleboards an industrial softwood blend and plum pruning waste were used. Plum branches were obtained from an orchard after maintenance pruning. The wood particles were produced by crushing the biomass into chips on a disc chipper, and then, by milling it in a laboratory knife mill. The particles were dried then to a moisture of 10% and sorted in accordance to their purpose to core and face layer fractions. The core layer particles passed through the 4 mm mesh and were retained by the 2 mm mesh. The particles used for face layer passed through the 2 mm mesh and were retained by the 0.25 mm mesh.

Particleboards

Three-layer particleboards with none (0%) and varied content of plum pruning waste (25%, and 50%) were manufactured with a nominal density of 650 kg/m^3. Particleboards thickness was 16 mm and face layer constituted 35% of total particleboard. Resination of particleboards was done with a UF (Silekol 123) urea-formaldehyde resin, and consisted in 10% for the face layers, and 8% for the core layer. A 10% ammonium sulfate solution was used for hardening. The unit formulation of the adhesive was 50:15:1.5 parts by weight of resin, water, and hardener, respectively. The particles were glued using the pneumatic spray method. The process of particleboards pressing was conducted in a single-shelf press at a temperature of 180°C, under 2.5 MPa, and pressing time 325 s. The pressure was reduced during the process to achieve aimed thickness of the Particleboards. Manufactured particleboards were conditioned for 7 days at 20±2ºC and 65±5% relative moisture content.

Mechanical and physical parameters

The manufactured particleboards have been tested to the following parameters:

- static bending strength (MOR) and modulus of elasticity in static bending (MOE) according to the PN-EN 310: 1994 standard,
- tensile strength in the direction perpendicular to the particleboards planes (IB), according to the PN-EN 319: 1999 standard,
- thickness swelling (TS) after soaked in water for 2 hours (2 H) and 24 hours (24 H) was determined based on the (EN 317, 1999) standard,
- water absorption after soaked in water for 2 hours (2 H) and 24 hours (24 H). The test consisted in comparing the weight of the sample before soaking to the weight of the sample after soaking in water. The designation was based on the formula:

$$WA = \frac{m_f - m_0}{m_0} \cdot 100\% \tag{1}$$

where: WA is water absorption, m_0 is the weight of the sample before soaking [g], and m_f is the weight of the sample after soaking [g].

To study the effect of applied plum pruning waste on particleboards' properties, a one-way ANOVA was conducted. Tukey's test was used to examine the significance of differences among individual values at p = 0.05.

Results and Discussion

The one-way analysis of variance revealed a significant influence of the plum material on the static bending strength and the modulus of elasticity of the manufactured particleboards. It should be marked, that a significant difference was reported only between reference material and particleboards containing plum wood (Table 1). No significant difference was found between particleboards containing 25% and 50% of plum material, which may indicate that deterioration of studied properties occurs already when added from 1 to 25% of plum pruning waste. Results obtained for mechanical properties tests are in general in coincidence with statements in the literature concerning a decrease in mechanical properties of particleboards manufactured with the addition of particles made from fruit trees (Auriga et. al. 2019, Kowaluk et al. 2019).

It is worth noting that despite the reduction in the strength properties of particleboards containing plum wood, all the particleboards have met the requirements of P2 boards for interior fitments (including furniture) for use in dry condition specified in the EN 312 standard (min. 11 N/mm^2). The observed relationships are consistent with the reports of Kowaluk et al. (2019). The authors revealed that particleboards made of plum wood had lower mechanical properties than industrial boards, and still met the requirements for P2 boards specified in EN 312.

Table 1. Mechanical properties of particleboard
Tabela 1. Właściwości mechaniczne wytworzonych płyt wiórowych

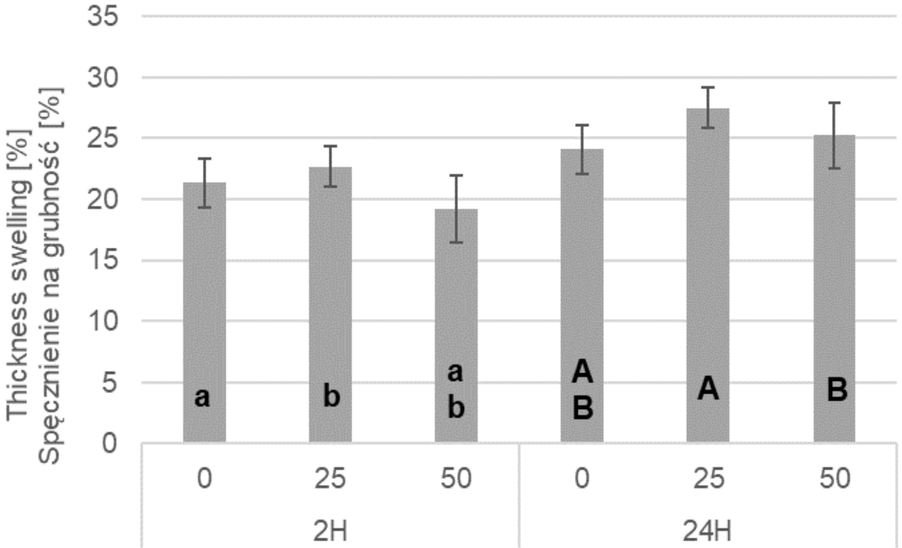
Share of plum wood particles	MOR [N/mm^2]		MOE [N/mm^2]		IB [N/mm^2]	
	Average	St. Dev.	Average	St. Dev.	Average	St. Dev.
0	15.64^a	1.41	3122^a	269	0.42^b	0.06
25	13.43^b	0.94	2604^b	152	0.52^a	0.08
50	13.44^b	1.95	2614^b	357	0.38^b	0.09

a, b, c - homogeneous groups by Tukey's test (α = 0.05)
St. Dev. - standard deviation

Figure 1. shows the results of the thickness swelling test for manufactured boards. The findings indicate that particleboards containing plum pruning waste generally had higher thickness swelling values comparing to particleboards made of softwood. This does not corroborate with the findings of Kowaluk et al. (2019), whose indicated that the thickness swelling of plum wood particleboards is lower than that of the reference boards. Perhaps, such factors as: age, bark content, size of particles, and presence of nonstructural

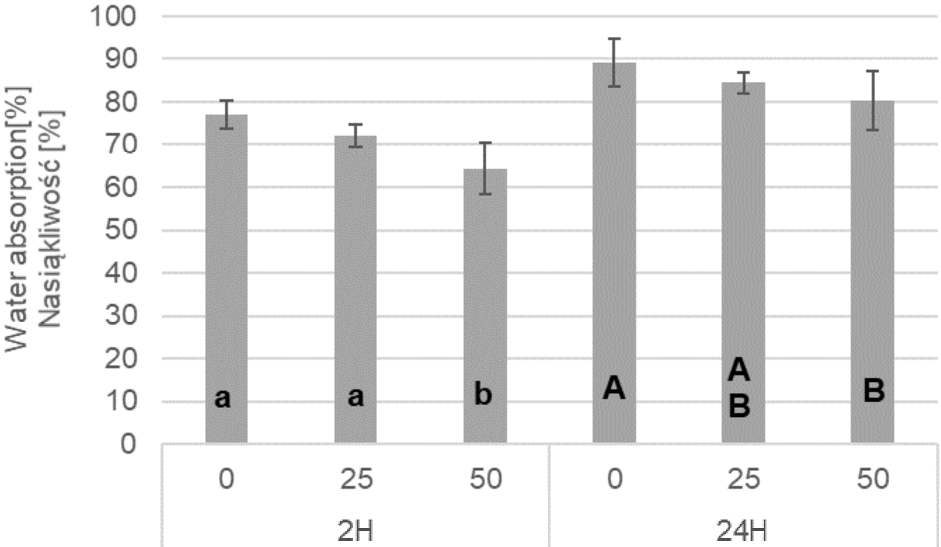
substances in the plum pruning waste material play a significant role in thickness swelling capability.

Outcomes obtained in the water absorption test showed reverse dependency comparing to thickness swelling results (Fig. 2). Particleboards containing plum pruning waste were characterized by a lower water absorption than softwood particleboards.



abc ABC - grupy homogeniczne wyznaczone przy wykorzystaniu testu Tukeya
abc ABC - homogeneous groups determined using Tukey's test

Fig. 1. Thickness swelling values of tested boards
Rys. 1. Wartości spęcznienia na grubość badanych płyt



abc ABC - grupy homogeniczne wyznaczone przy wykorzystaniu testu Tukeya
abc ABC - homogeneous groups determined using Tukey's test

Fig. 2. Water absorption values of tested boards
Rys. 2. Wartości nasiąkliwości badanych płyt wiórowych

Conclusions

Based on the research, the following conclusions can be drawn:

1. The share of plum wood obtained from maintenance pruning decreased the strength properties of manufactured boards. However, the still met the EN 312 standards for P2 boards.
2. Particleboards containing plum pruning waste were characterized by generally higher values of thickness swelling and lower values of water absorption compared to softwood boards.

Plum waste material obtained from maintenance pruning can be an alternative feedstock utilized in the production of particleboards.

References

Auriga R., Borysiuk P., Gumowska A., Smulski, P., 2019: Influence of apple wood waste from the annual care cut on the mechanical properties of particleboards. Annals of Warsaw University of Life Sciences - SGGW, Forestry and Wood Technology 105, 47-53. ISSN 1898-5912.

Banjo Akinyemi A., Afolayan J., Oluwatobi E., 2016: Some properties of composite corn cob and sawdust particle boards. Construction and Building Materials 127, 436-441.

Borysiuk P., Laskowska A., 2009: Particleboards with grass plant additive. Annals Warsaw University of Life Sciences - SGGW, Forestry and Wood Technology 68, 463-466.

Cichy W., Witczak M., Walkowiak M., 2017: Fuel properties of woody biomass from pruning operations in fruit orchards. BioResources 12, 6458-6470. https://doi.org/10.15376/biores.12.3.6458-6470

Dyjakon A., Boer J., den Bukowski P., Adamczyk F., Frąckowiak P., 2016: Wooden biomass potential from apple orchards in Poland. Drewno 59, 73-86. https://doi.org/10.12841/wood.1644-3985.162.09

Gorzelany J., Matłok N., 2013: Analiza energetyczna biomasy odpadowej z produkcji drzewek owocowych na terenie województwa podkarpackiego. Inżynieria Rolnicza 3, 77-83.

Klímek P., Meinlschmidt P., Wimmer R., Plinke B., Schirp A., 2016: Using sunflower (*Helianthus annuus* L.), topinambour (Helianthus *tuberosus* L.) and cup-plant (*Silphium perfoliatum* L.) stalks as alternative raw materials for particleboards. Industrial Crops and Products 92, 157-164. https ://doi.org/10.1016/J.INDCROP.2016.08.004

Klugmann-Radziemska E., 2015: Odnawialne źródła energii. Przykłady obliczeniowe. Wydawnictwo Seidel-Przywecki, Gdańsk.

Kowaluk G., Kądziela J., 2014: Properties of particleboard produced with use of hazelnut shells. Annals Warsaw University of Life Sciences - SGGW. Forestry and Wood Technology 85, 131-134.

Kowaluk G., Szymanowski K., Kozłowski P., Kukuła W., Sala C., Robles E., Czarniak P., 2019: Functional assessment of particleboards made of apple and plum orchard pruning. Waste and Biomass Valorization 11, 2877-2886.

Mahieu A., Vivet A., Poilane C., Leblanc N., 2021: Performance of particleboards based on annual plant byproducts bound with bio-adhesives. International Journal of Adhesion and Adhesives 107. https://doi.org/10.1016/j.ijadhadh.2021.102847

Pawlak D., Jenczyk-Tołłoczko I., Boruszewski P., 2018: Analysis of selected properties of particleboard modified with Miscanthus giganetus JM Greef & Deuter ex Hodk. & Renvoize. Annals of Warsaw University of Life Sciences - SGGW. Forestry and Wood Technology 102, 149-156.

Rabcewicz J., Wawrzyń P., Konopacki P. 2007: Określenie ilości drewna pozyskiwanego z cięcia drzew i krzewów owocowych do wykorzystania w celach energetycznych.

Sekaluvu L., Tumutegyereize P., Kiggundu N., 2014: Investigation of factors affecting the production and properties of maize cob particleboards. Waste and Biomass Valorization 5, 27-32. https://doi.org/10.1007/s1264 9-013-9228-9

Suwan A., Sukhwipat N., Uthaipan N., Saetung A., Saetung N., 2020: Some properties of experimental particleboard manufactured from waste bamboo using modified recycled palm oil as adhesive. Progrss in Organic Coatings. 149. https://doi.org/10.1016/j.porgcoat.2020.105899

Warmbier K., Danecki L., Majtkowski W., 2016: Mechanical properties of one-layer experimental particleboards from shoots of tall wheatgrass and industrial wood particles. Annals of Warsaw Agricultural University - SGGW. Forestry and Wood Technology 96, 237-240.

List of standards

EN 310:1994 Wood-based panels - determination of modulus of elasticity in bending and of bending strength. Brussels.

EN 312:2011 Particleboards - Specifications

EN 317:1999 Particleboards and fibreboards - determination of swelling in thickness after immersion in water. Brussels.

EN 319:1999 Particleboards and fibreboards - determination of tensile strength perpendicular to the plane of the board. Brussels.

Reviewed paper / Artykuł recenzowany
Submitted / Zgłoszony: 05.05.2021
Published online / Opublikowany online: 25.06.2021