

PRACE NAUKOWE – RESEARCH PAPERS

Iwona FRĄCKOWIAK, Dorota FUCZEK, Grzegorz KOWALUK

IMPACT OF DIFFERENT LIGNOCELLUOSIC MATERIALS USED IN CORE OF PARTICLEBOARD ON MODULUS OF ELASTICITY AND BENDING STRENGTH

The aim of the research was to investigate the possibilities of partial substitution of conventional wood with alternative raw materials without raising the costs. One of the advantage of this kind of materials is that chips with different geometry can be made from agricultural lignocellulosic materials in contrast to wood waste commonly used for wood based panels production. Results of investigation shows that with use the typical chipper, it is possible to produce the chips with proper geometry from the agricultural alternative lignocellulosic raw materials, and with partial substitution of conventional chips in core layer of three-layer panel by chips from alternative lignocellulose raw materials, there is possibility to produce the particleboards with bending strength and modulus of elasticity higher than for panels produced in the same conditions from typical industrial chips. Panels produced with use of alternative lignocellulosic agricultural raw materials fulfil the requirements of the proper standard for furniture panels in range of bending strength and modulus of elasticity in bending.

Keywords: particleboard, agricultural lignocellulosic materials, bending strength, modulus of elasticity

Introduction

Nowadays we have been facing the problem of the decrease of wood resources for wood based panels production. According to the forecast of FAO the forest

Iwona FRĄCKOWIAK, Wood Technology Institute, Poznań, Poland

e-mail: i_frackowiak@itd.poznan.pl

Dorota FUCZEK, Wood Technology Institute, Poznań, Poland

e-mail: d_fuczek@itd.poznan.pl

Grzegorz KOWALUK, Wood Technology Institute, Poznań, Poland

e-mail: g_kowaluk@itd.poznan.pl

area of our planet which in 1960 was 1.17 ha per capita will decrease to 0.47 ha per capita in 2010 [Bechta 2003]. This problem does not concern all countries in the same way but it is becoming a global issue at the moment of decrease of forest area which causes irreversible environment damage.

Recently more attention has been devoted to the usage of agricultural and other annual plants for wood based panels production. Evaluation of global biomaterials resources showed that there is over 4 billion tons of biomaterials, including 1.75 billion of wood and 1.15 billion tons of different kinds of straw [Rowell 2004].

To prove the importance of the subject many investigations on the bio-materials uses has been carried out. For example in the USA, in the eighties only during one project called Growing Industrial Materials over two thousands species of plants were tested from a different angle of industrial usage [Bertram 1992]. The results showed that a few dozen of the tested species were recommended for cultivation. In Europe the research on cultivation and plants use for the industry purpose has been still in progress. From 1994 to 1998 two – hundred projects had been fulfilled by many institutions, universities and commercial companies. Also in Poland the research has been carried out in the field of the usage of fast growing plants for industry. In 2004, in Wood Technology Institute in Poland, in Wood-Based Materials and Glues Department the research was carried out on the usage of a rape straw and a fast growing willow tree for the wood-based panels production. Production possibilities of single-layer 12 mm thick particleboards made of rape straw particles and different types of resin (UF, MUPF, PF, PMDI) were investigated also by Dziurka et al. [2005], as well as Dukarska et al. [2006].

The aim of the research was to investigate the possibilities of partial substitution of conventional wood with alternative raw materials without raising the costs. One of the advantage of this kind of materials is that chips with different geometry can be made from agricultural lignocellulosic materials in contrast to wood waste commonly used for wood based panels production. The composition of chips made from agricultural lignocellulosic materials with wood raw materials in different proportion create possibilities of getting panels with different structure, density and durability. This subject is a global issue and it is compatible with the EU directive on the development of agricultural land for cultivation plants not intended for food purposes.

Materials and methods

For the purpose of this investigation three-layers particleboards with the core made from different agricultural and other annual plants were produced. Four different plants were selected:

- robinia (*Robinia pseudacacia L.*),

- miscanthus (*Miscanthus sinensis giganteus*),
- willow (*Salix viminalis*),
- rapeseed (*Brassica napus*).

The choice was dictated by the possibilities and conditions of the cultivations as well as special features of those plants. From listed plants unlike frequently used wood materials, chips with different geometry can be obtained. Especially longer chips used in core has matter. The assumption was made that the usage of this kind of chips should increase bending strength or impact on economy of lignocellulosic materials which is a basic element of the direct cost. Thereby, this solution should decrease wood deficit, which recently has been a main problem of the wood-based panels sector.

Characterization of lignocellulosic raw materials

Robinia (*Robinia pseudacacia L.*) – it is a plant brought to Europe in XVII century. In Romania and Hungary robinia is cultivated on plantation with a very good productivity [Zabielski 1998, Zajączkowski 2007, Zajączkowski et al. 2003]. In Poland it is also known plant which nowadays is consider as a very precious species mainly because of its low requirements in case of soil, resistance to spring ground frost, good adaptation to drought and salty soil [Kościk 2003]. Only marshy ground is not desired. Right now there is no plantation of Robinia in Poland. The material for this research was obtain within the framework of cleaning cut from the forest in Poznań area.

Miscanthus (*Miscanthus sinensis giganteus*) – belongs to large perennial grass native to China, Japan, Russia, Taiwan and the USA. It can grow up to 5 m with even up to 5 cm in diameter. In Europe Miscanthus has been grown for about 50 years, initially as a decorative plant, presently as a source of biomass for the production of energy [Kościk 2003]. Miscanthus can be cultivated on lower-class soil with pH of the soil close to 6.5. Besides average annual rainfall should be close to 600 mm and average annual temperature around 8°C. The samples of miscanthus giganteus were taken from experimental plantation of Polish Academy of Sciences in Poznań.

Willow (*Salix viminalis*) – belongs to willow plants with about 350 species. An important feature of salix viminalis is a very fast growth of its organic mass even 10 times bigger than in case of pine or spruce [Kościk 2003]. Productivity of a cultivation depends on a number of factors like the type of clone, class of soil, the cycle of harvest and also the level of groundwater [Szczukowski and Tworkowski 2001]. Many researches has been carried out on the use of this species. The dominant direction of the uses is the production of energy. But also wood-based panels were experimentally produced with comparable and even better properties than described in available at that time standards. For presented research Salix viminalis was obtained from the plantation of two-years varieties of ULV, JORR and BJORN in Marzęcin in Poland.

Rapeseed (*Brassica napus*) – it is a member of the cabbage family (Brassicaceae or Cruciferae). Rapeseed is suitable to be grown in regions that have colder climatic conditions, such as, Northern Europe, China, India, Canada, higher and colder areas of South America. In Poland rapeseed is cultivated on over 700 thousand hectares. The popularity of this plant among planters is dictated mostly by economy, and good impact its roots' system on soil fertility. It is primarily cultivated for animal feed and source of vegetable oil. There is also an idea of the usage of rape straw as an alternative raw material in wood based panels production which follows from planned dynamic growth of rapeseed's cultivation. The research on a rape straw use in the wood-based panels production was conducted as early as the sixties [Kontek 1961]. Characteristics of rape straw, its chemical compositions, study on wood based panels production technology and economy foundations of possible wood-based panels production was described by Frąckowiak and Kilanowski [1965]. In the presented research two types of rape straw were used: yellow and grey. The difference between yellow and grey rape straw was connected with storing.

Obtained material was subjected to sorting analysis. The results were shown in the fig. 1. During the research the fractions of the chips smaller than 10 mm and bigger than 1 mm were used for the core. The content of the fractions of robinia, willow and miscanthus were comparable to determined industrial chips. In case of robinia the content of the fraction smaller than 1 mm was about 11% and for grey rape straw close to 32%. That was caused, in some way, by efficiency of Allgaier sorter but first and foremost by the sort of particles with its susceptibility to break up.

The particles obtained from different lignocellulosic materials varied in shape. On the basis of visual evaluation it is possible to conclude that particles made from robinia, willow and yellow rape straw can be described as flat chips, from miscanthus as chips in the shape of a needle and from grey rape straw as chips in the shape of splinter. The data of shape factor (table 1) showed that all tested lignocellulosic materials were more sleek and flat. Moreover it is worth to emphasize a variety of the specific surface of the particular sort of materials. The calculated data of the specific surface, for the particles of miscanthus, grey rape straw and yellow rape straw, were respectively twice, three and almost four times bigger than in case of robinia, willow, and pine.

For the production of particleboards the stalks of robinia, miscanthus, willow and also rape straw was reduced in size with a Pallmann's chipper. The chips were used for three-layer boards of 16 mm thickness, with raw densities 680 kg/m³ and UF resin. Besides technological parameters like drying conditions, moisture content of lignocellulosic particles after drying, resination, type and amount of hardener and paraffin emulsion, method of forming, temperature and pressing schedule and also conditions of panels seasoning were constant and

close to industrial parameters. The properties of the resultant boards were compared with reference particleboards with the core made from pine chips.

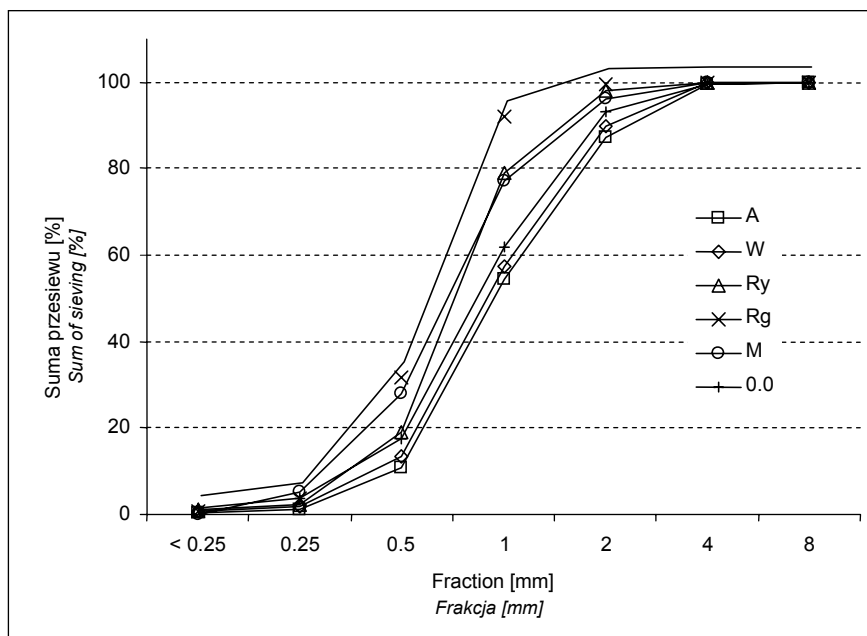


Fig. 1. Curves of summation of the lignocellulosic parts fraction share (A – robinia chips, W – willow chips, Ry – yellow rape chips, Rg – grey rape chips, M – miscanthus chips)

Rys. 1. Krzywe sumacji składu frakcyjnego cząstek lignocelulozowych stosowanych do wytwarzania płyt (A – wióry z robinii, W – wióry z wierzy, Ry – wióry ze słomy żółtej Rg – wióry ze słomy szarej, M – wióry z miskanta)

The changeable factors of particular variants, like sort of lignocellulosic materials, was presented in table 2.

Testing methods referred to European Standards EN 323 in case of density, EN 322 in case of moisture, and EN 310 in case of bending and modulus of elasticity in bending. The average density of all investigated panels was about 677 kg/m^3 , and the variation coefficient of the density of the panels was less than 4%. Before mechanical tests the samples were stored in climatic chamber (20°C , 65% R.H.). The range moisture content of the investigated panels was from 7.9 to 8.2%.

Table 1. Geometry of the chips used for the core of particleboards
Tabela 1. Geometria wiórów użytych do wytworzenia warstwy środkowej płyty wiórowych

Parametr <i>Parametr</i>	Value <i>Wartość</i>	Industrial chips* <i>Wióry przemysłowe*</i>	Chips raw material <i>Surowiec na wióry</i>				
			Robinia <i>Robinia</i>	Grey rape straw <i>Słoma rzepakowa szara</i>	Yellow rape straw <i>Słoma rzepakowa żółta</i>	Willow <i>Wierzba</i>	Miscanthus <i>Miskant</i>
Length [mm] <i>Długość [mm]</i>	x	6.6	15.7	9.9	11.0	15.3	23.5
	u	0.41	1.34	0.54	0.67	0.83	1.82
	n	491	343	547	385	498	190
Thickness [mm] <i>Grubość [mm]</i>	x	1.39	2.50	1.711	1.89	2.03	2.48
	u	0.90	0.21	0.11	0.14	0.12	0.28
	n	491	343	547	385	498	190
Width [mm] <i>Szerokość [mm]</i>	x	0.59	0.46	0.38	0.33	0.49	0.43
	u	0.012	0.038	0.036	0.029	0.042	0.045
	n	491	343	547	385	498	190
Slenderness ratio <i>Stopień smukłości</i>	x	11	34	26	33	31	54
Flatness ratio <i>Stopień płaskości</i>	x	2	5	4	6	4	6
Density [kg/m ³] <i>Gęstość [kg/m³]</i>	x	490	447	190		423	270
Specific surface [m ² /kg] <i>Powierzchnia właściwa [m²/kg]</i>	F _w	10.5	10.7	31.1	38.0	12.3	20.5

x – arithmetic mean; *średnia arytmetyczna*.

u – confidence level, where $\alpha = 0.05$; *poziom ufności przy $\alpha = 0.05$* .

n – number of samples; *liczba próbek*.

* industrial chips obtained in 95% from pine wood; *wióry przemysłowe uzyskane w 95% z drewna sosny*.

** specific surface: $F_w = 2/\rho_0[l^{1/3}+b^{1/3}+a^{1/3}]$ [m²/kg], where: ρ_0 – density of oven-dry board, l, b, a – average length, thickness, width; *powierzchnia właściwa, gdzie: ρ_0 – gęstość próbki, l, b, a – przeciętna długość, grubość, szerokość*.

Table 2. Changeable factors in particular variants**Tabela 2. Czynniki zmieniane w poszczególnych wariantach**

Variant <i>Wariant</i>	Sort and quantity (%) of lignocellulosic particles in core layer <i>Rodzaj i ilość (%) cząstek lignocelulozowych w warstwie środkowej</i>
0.0	Industrial pine chips <i>Przemysłowe wióry sosnowe</i>
0.1	Pine sawdust <i>Trociny sosnowe stolarskie</i>
A	Industrial pine chips (75), (25) <i>Przemysłowe wióry sosnowe (75), wióry z robinii (25)</i>
M	Industrial pine chips (75), particles of miscanthus (25) <i>Przemysłowe wióry sosnowe (75), cząstki miskanta (25)</i>
Ry	Industrial pine chips (75), particles of yellow rape straw (25) <i>Przemysłowe wióry sosnowe (75), cząstki słomy rzepakowej żółtej (25)</i>
Rg	Industrial pine chips (75), particles of grey rape straw (25) <i>Przemysłowe wióry sosnowe (75), cząstki słomy rzepakowej szarej (25)</i>
W	Industrial pine chips (75), willow chips (25) <i>Przemysłowe wióry sosnowe (75), wióry z wierzby (25)</i>

Results and discussion

Three-layer particleboards with the core made from described above plants were tested in terms of bending strength and MOE. The results of bending strength tests are presented in fig. 2. The bars 0.0 and 0.1 show the results of the bending strength of the panels produced from industrial pine chips, and pine sawdust, respectively. Rest of the bars (A, M, Ry, Rg, W) present the bending strength for the panels produced with the use of alternative raw materials, described above. As it is shown, the lowest bending strength was for panels produced from industrial chips and sawdust (0.0 and 0.1). Bending strength of the rest of panels was more equal and higher than the panels without alternative lignocellulose raw materials. It should be mentioned, that all the panels produced with the use of alternative lignocellulose parts fulfil the requirements of the PN-EN 312 standard in case of bending strength for furniture panels (13 N/mm^2). Additionally, the bending strength of the W-panel (willow) fulfils the requirements of above mentioned standard for P4-type panel.

The results of the measurement of the modulus of elasticity in bending for investigated particleboards are shown on fig. 3. These results are strongly correlated to above mentioned results of the bending strength. The lowest values of the modulus of elasticity was for 0.0 and 0.1 panels, and the highest value of the MOE was for W (willow chips) panel. Rest of the panels has significantly equal modulus of elasticity. It is important to say that all the panels produced from chips from alternative lignocellulose raw materials fulfil the requirements

of the PN-EN 312 standard for P4-type panels in case of modulus of elasticity (2300 N/mm^2).

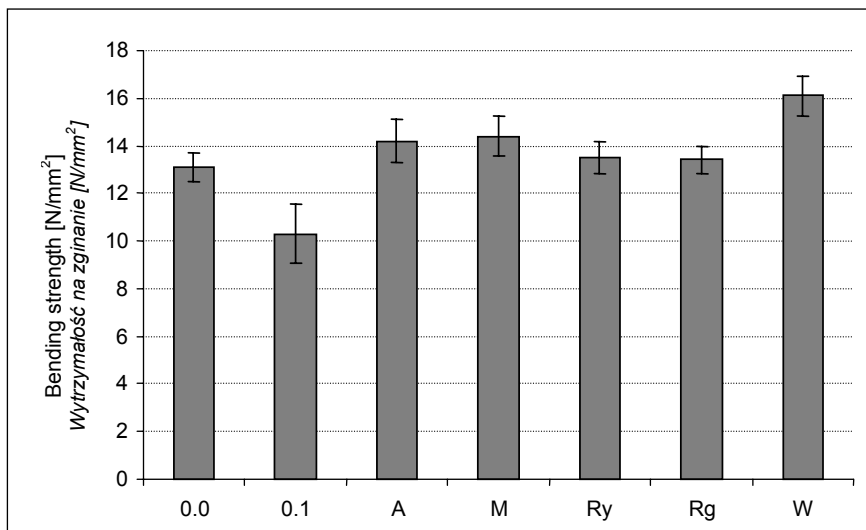


Fig. 2. Bending strength of investigated particleboards

Rys. 2. Wytrzymałość na zginanie badanych płyt wiórowych

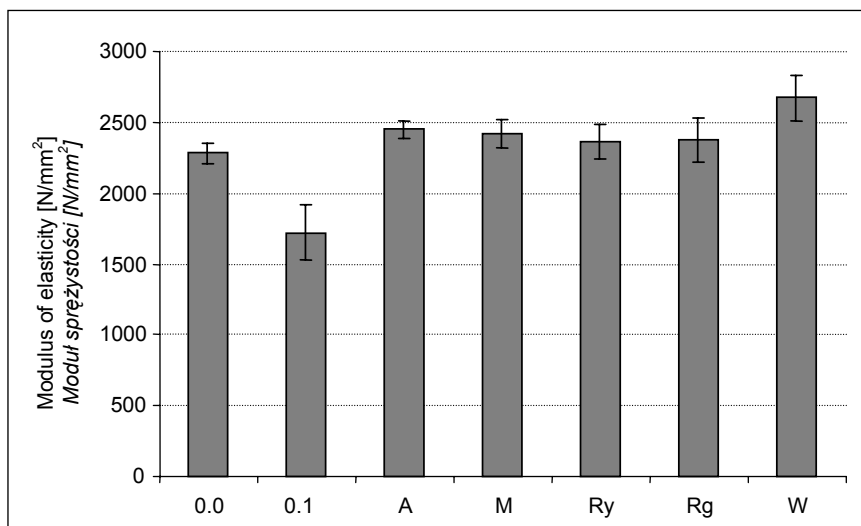


Fig. 3. Modulus of elasticity in bending of investigated particleboards

Rys. 3. Moduł sprężystości przy zginaniu badanych płyt wiórowych

Conclusions

Above mentioned results show that it is possible to produce the three-layer particleboards with the use of the chips obtained from alternative lignocellulosic raw materials on the conventional chipper for core layer. The production parameters of these panels (pressing time factor, pressure, temperature, resination, resin type etc.) were close to industrial conditions. Panels produced with the use of the chips from alternative lignocellulose raw materials for core layer have the bending strength and modulus of elasticity higher than panels produced from pine sawdust or industrial chips, and fulfil the requirements (bending strength and the modulus of elasticity in bending) of the suitable standards for the panels designed to furniture production.

Finally, it should be mentioned, that with the proper utilization of the chips from investigated alternative raw materials, even as a partial substitution of conventional raw material, it is possible to produce the panels designed to finishing, with improved strength, regarding to presently produced particleboards.

References

- Bechta P.** [2003]: Płyty ze słomy: stan obecny i perspektywy rozwoju. Tłumaczenie z j. ros.: Oniśko W. Biul. Inf. OBRPPD [1-2]
- Bertram R. B.** [1992]: New Crops and the International Agricultural Research Centers. New Crops. Ed. J. Willey & Sons, New York
- Dukarska D., Dziurka D., Łęcka J., Mirski R.** [2006]: The effect of amounts of rape straw added to chips on properties of particle boards depending on the type of bonding agent. EJPAU 9[3]
- Dziurka D., Mirski R., Łęcka J.** [2005]: Properties of boards manufactured from rape straw depending on the type of the binding agent. EJPAU 8[3]
- Frackowiak A., Kilanowski W.** [1963]: Badania nad otrzymywaniem płyt z cząstek lignocelulozowych słomy rzepakowej. Pr. Inst. Kraj. Włók. Natur. R. XI: 141–153
- Kontek W., Ławniczak I.** [1959]: Możliwość wykorzystania słomy rzepakowej jako domieszki w produkcji płyt izolacyjnych. Przemysł Drzewny [10]:16–18
- Kościk B.** (Red.) [2003]: Rośliny energetyczne. Wyd. AR, Lublin
- Orwińska L.** [2004]: Dziesięciolecie doświadczenia z plantacji wierzby w Marzęcinie. Czysta Energia 36[10]
- Rowell R. M.** [2004]: Czynniki determinujące przyszłość biokompozytów. Biul. Inf. OBRPPD [3-4]
- Szczukowski S., Tworkowski J.** [2001]: Produktywność oraz wartość energetyczna biomasy wierzb krzewiastych *Salix* sp. na różnych typach gleb w pradolinie Wisły. Postępy Nauk Rolniczych [2]
- Zabielski S.** [1998]: Plantacyjna uprawa drzew i krzewów szybko rosnących. Wyd. AR, Poznań

Zajączkowski K. [2007]: Robinia akacyjowa jako roślina energetyczna. Album roślin energetycznych. Wokół energetyki

Zajączkowski K., Tałaj Z., Węgorzek T., Zajączkowska B. [2003]: Dobór drzew i krzewów do zadrzewień na obszarach wiejskich. Wyd. IBL, Warszawa

<http://bioenergia.bp.webpark.pl/owierzbie.html>

<http://wierzba.webpark.pl/pliki/wierzba.html>

<http://www.fao.org/>

<http://www.lasprywatny.pl/poradnik.html>

<http://www.wrp.pl/>

PN-EN 312 : 2005 – Płyty wiórowe – Wymagania techniczne

PN-EN 323 : 1999 – Płyty drewnopochodne. Oznaczanie gęstości

PN-EN 322 : 1999 – Płyty drewnopochodne. Oznaczanie wilgotności

WPLYW RODZAJU CZĄSTEK LIGNOCELULOZOWYCH W WARSTWIE WEWNĘTRZNEJ PŁYT WIÓROWYCH NA ICH WYTRZYMAŁOŚĆ NA ZGINANIE I MODUŁ SPRĘŻYSTOŚCI

Streszczenie

Celem pracy było zbadanie możliwości częściowej substytucji drewna w warstwach środkowych płyt wiórowych przez alternatywne materiały (surowce lignocelulozowe pochodzenia rolniczego) bez wzrostu kosztów. Jedną z zalet tych materiałów jest możliwość wytworzenia z nich wiórów o założonej geometrii, w odróżnieniu od odpadów drzewnych, powszechnie wykorzystywanych w produkcji płyt wiórowych. Wyniki badań wykazały, iż przy użyciu typowego młyna, można otrzymać wióry o właściwej geometrii z alternatywnych surowców lignocelulozowych pochodzenia rolniczego. Częściowa substytucja konwencjonalnych wiórów w warstwie środkowej płyty trójwarstwowej przez wióry z materiałów alternatywnych pozwala na wytwarzanie płyt wiórowych o wytrzymałości na zginanie oraz module sprężystości wyższym niż dla płyt wytwarzanych w tych samych warunkach z wiórów przemysłowych. Otrzymane w ten sposób płyty spełniają wymagania normy dla płyt meblowych w zakresie wytrzymałości na zginanie statyczne oraz modułu sprężystości przy zginaniu.

Słowa kluczowe: płyta wiórowa, materiały lignocelulozowe pochodzenia rolniczego, wytrzymałość na zginanie, moduł sprężystości