Annals of Warsaw University of Life Sciences – SGGW
Forestry and Wood Technology No. 110, 2020; 73-78
(Ann. WULS–SGGW, For. and Wood Technol. 110, 2020)

A potential of non-energy use of agricultural residues and energy plants in lignocellulosic composites production. A brief report

ANITA WRONKA, GRZEGORZ KOWALUK
Department of Technology and Entrepreneurship in Wood Industry, Faculty of Wood Technology / Institute of Wood Sciences and Furniture, Warsaw University of Life Sciences – SGGW

Abstract: There is a systematic increase in the use of wood waste as raw material in particleboard production, but in the face of an upward trend in particleboard demand, these activities are insufficient. Therefore, there arises the necessity of using materials whose resources are renewable easier (faster) than forest resources, or materials which are considered waste. Such materials could be: "energetic" willow (*Salix Viminalis* L.) and rape straw. In the case of willow, its production potential quite often cannot be fully utilized in an "energy production" way, due to consumers' requirements and capabilities. In the case of rape straw, which is regarded as waste material (in more optimistic scenarios – as a side product) in agricultural production, it is known, that the amount of this material will increase, because of the EU regulations, concerning biofuels. Today only 2–3% of rape straw is industrially utilized. The results of research show that appropriate preparation of the mentioned alternative raw material and adjustment of technological parameters give a possibility to produce particleboards of parameters equal to, or even higher than, those of typical, commercially available boards. The research confirmed the possibility of replacing industrial wood shavings with rapeseed straw particles even in 50% without significantly worsening the properties of the manufactured boards. The strength and thermal insulation parameters of boards with reduced density, made of *Salix Viminalis* L. willow particles, are also promising.

Keywords: particleboard, bending, strength, compression, rape straw, willow

INTRODUCTION

Forest resources of our planet decrease at an alarming rate (Bekhta 2003). According to a FAO report, the globe forestation in 1960 was 1.17 ha per head, and in 2010 was only 0.47 ha per head. Such intensive forest exploitation is caused by many factors, including among others a rapid increase of wood-based panel production. According to the European Panel Federation (European Panel Federation Report 2006), 60 mln m^3 of wood-based panels was produced in 2005 in Europe, excluding Russia. Particleboards accounted for the majority of this production (63%). The increase in production of particleboards was about 12% from 2002 to 2005. This situation forces us to look for other prospective sources of raw material.

There have been attempts to introduce alternative raw materials into wood-based panel production. One of them is to use rape straw as a substitute for conventional wood raw material. Kontek and Ławniczak (1959) says that partial substitution of wooden particles in the core layer of the board with rape straw parts results in reduction of strength in comparison to boards made solely of wooden particles. Production of the board core layer from a mixture of rape straw parts and wooden particles leads to increase in strength compared to boards made solely of wooden particles. A decrease in strength caused by substitution of wooden material with rape straw in the production of particleboards was described by Pałubicki *et al.* (2003). The results of research on the use of rape straw in the production of particleboards conducted in the Wood Technology Institute in Poznan, Poland, were interesting (Frąckowiak 2004, 2007). According to this research, there is a possibility to produce particleboards from rape straw particles using urea-formaldehyde resins. These

boards meet the requirements for particleboards intended for furniture production and interior furnishing (P2 type according to EN 312:2010 standard).

Willow *Salix Viminalis* L., a plant popular for energy plantations crops, is characterized by faster organic mass growth than pine and/or spruce. Willow biomass is mainly used for energy production purposes. However, there is some research on the production of boards from willow. According to Morze and Prądzyński (1971), it is possible to produce particleboards from willow which are characterized by parameters equal to or even higher than those given in standards for particleboards. The results of latest research of the Wood Technology Institute in Poznan, Poland, confirm these conclusions (European Panel Federation Report 2006). Warmbier *et al.* (2013) confirm in their research that the growing share of willow particles in the board has a positive effect on the resistance to axial pulling of the screws as well as on internal bonds

The aim of this paper was to present the results of chosen investigations of the production of particleboards of different purposes from alternative lignocellulose raw materials and agricultural waste. The assumption was to use alternative raw material as a substitute for conventional wooden material. The scope of the research encompassed investigation of the influence of the degree of substitution of conventional wooden material with an alternative one and of the influence of resin modification on the properties of particleboards.

MATERIALS AND METHODS

Tested materials

The investigations were conducted with the use of two types of alternative raw materials: rape straw and willow *Salix Viminalis* L. A group of boards made of typical industrial particles or waste saw dust was the reference material. Part of the above mentioned lignocellulosic raw materials has been obtained from the standard cross grinding machine. The three-layer particleboards (32% of face layers, w/w), resinated (glued) by urea-formaldehyde (UF) resin Silekol W1-C, 12 and 10% face and core layer, respectively, 650 kg/m^3 nominal density, were produced in semi-industrial way with the use of a computer controlled shelf press, to compare with the requirements for furniture panels (P2 type) according to EN 312:2010 standard. In the case of rape straw the amine resin was modified by resorcinol, phenol and melamine during condensation as well as the molar ratio of resin (Frąckowiak 2006) (the detailed information about resin modification has been classified due to high commercialization potential). There were also lightweight panels (of nominal density about 350 kg/m^3) produced from *Salix Viminalis* L. particles only, resinated by above mentioned UF resin with average ratio of about 10%, which have been compared to commercially available wood-based panels of insulation purposes.

Methods

The following parameters of the tested particleboards were investigated according to the adequate standards: static bending strength and modulus of elasticity (EN 310:1993), tensile strength (EN 312 – 2:1996), and formaldehyde content (EN 120:1994).

The boards from the group of lower density have been intended as insulating boards. The particles fractions, board density, resination (ranged between 8 and 12%) and glue type were changed for these boards. Internal bond (IB) (EN 319:1993), compression strength (PN-EN 826:1998) and heat transfer coefficient λ (EN 12667:2001) were measured for these boards.

RESULTS

Particleboards from rape straw

The results of measurement of bending strength of boards are displayed in fig. 1. According to this figure, the substitution of wooden material in the core layer of the board with rape straw particles results in improved bending strength. The reason for this can be higher compression (densification) of the non-pressed mat. It is a well-known and confirmed fact that surface layers are responsible for bending strength, since these are tensed and compressed, whereas the core layer is about to shear. In the case of investigated boards, rape straw particles have been added to the core layer. The achieved results show that the higher densification of the core layer made of rape straw particles helps with more optimal distribution of the stresses, where the face layers are less loaded and, thanks to this, the entire board can carry a higher load.

Modification of resin with resorcinol during condensation process causes a significant strength increase, especially perpendicular to the surface. Research on the influence of the urea-formaldehyde resin's molar ratio on the mechanical properties of particleboards produced with the use of rape straw parts shows a strong interrelation: static bending strength and tensile strength perpendicular to the board's surface increase as the formaldehyde-to-urea molar ratio, and swelling of board decreases. According to the results, a molar ratio of about 1.08 is needed for the board to achieve required mechanical parameters.

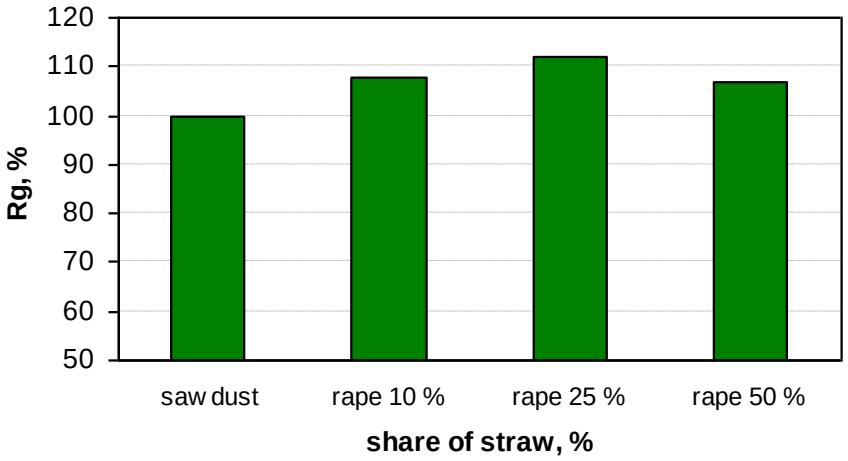

Figure 1. A comparison of the static bending strength of particleboards which have different proportion of straw in the core layer, in %; 100% – strength of boards from saw dust

Particleboards from willow Salix Viminalis L.

The values of static bending strength of three-layer boards produced from willow *Salix Viminalis* L. are displayed in fig. 2. According to this figure, the bending strength of the boards made solely of willow particles is more than 44% higher than that of the boards made of industrial particles. The tensile strength perpendicular to the surface (IB) was higher for the willow particles board than for the industrial particles board.

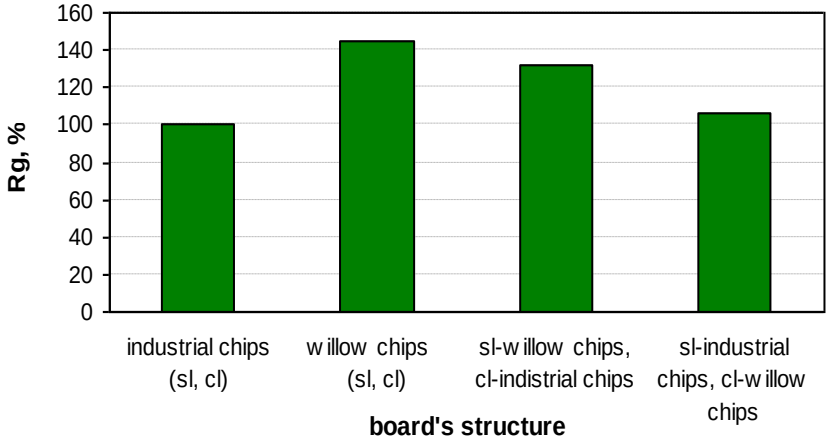

Figure 2. A comparison of the static bending strength of particleboards which have different material of the surface layer (sl) and core layer (cl), in %; 100% – strength of boards from industrial particles

Insulating boards from willow Salix Viminalis L.

Insulating particleboards were produced from particles of fast growing willow *Salix Viminalis* L. The results of measurement of chosen strength parameters of the insulating boards are as follows:

- strength for the tension perpendicular to the surface: 0.88–18.94 kPa,
- compression strength: 4.0–141.0 kPa.

The heat transfer coefficient λ: 0.043–0.051 W/(m*K). A close interrelation between the measured board's parameters and board's density was also found.

CONCLUSIONS

Conducted investigations show that there is a possibility to produce particleboards of desirable mechanical properties, even with a significant (50%) rape straw share. The optimal urea-formaldehyde molar ratio results in better mechanical parameters and lower swelling of boards in which conventional wooden material is substituted with rape straw.

Boards made of willow *Salix Viminalis* L. have higher mechanical parameters than boards made of typical industrial particles. The parameters of insulating boards made from willow are comparable to the parameters of commercially-available insulating materials made from wood fibres.

REFERENCES

1. BEKHTA, P. (2003): Płyty ze słomy: stan obecny i perspektywy rozwoju [Boards from straw: actual condition and development perspectives] [in Polish], Biul. Inf. Ośr. Bad.-Rozw. Przem. Płyt Drewnopoch. nr 1: 12–18
2. EN 120:1994 Wood-based panels – Determination of formaldehyde content – Extraction method called the perforator method
3. EN 12667:2001 Thermal performance of building materials and products – Determination of thermal resistance by means of guarded hot plate and heat flow meter methods – Products of high and medium thermal resistance
4. EN 310:1993 Wood-based panels - Determination of modulus of elasticity in bending and of bending strength
5. EN 312:2010 Particleboards – Specifications

6. EN 319:1993 Particleboards and fibreboards – Determination of tensile strength perpendicular to the plane of the board
7. European Panel Federation Report, 5th European Wood-based Panel Symposium, 4 – .10.2006, Hannover, Germany
8. FRĄCKOWIAK, I. (2004): Z badań nad wykorzystaniem słomy rzepakowej do produkcji płyt wiórowych [From the investigations on the utilization of the rape straw to particleboards production] [in Polish], DREWNO-WOOD, vol. 47, no. 171: 31–47
9. FRĄCKOWIAK, I. (2006): Wpływ stosunku molowego żywicy mocznikowo-formaldehydowej na właściwości płyt aglomerowanych z odpadowych surowców lignocelulozowych [Influence of the molar ratio of the urea-formaldehyde resin on the properties of the agglomerated boards from the waste lignocellulose raw materials] [in Polish], DREWNO-WOOD, vol. 49, nr 175: 71–86
10. FRĄCKOWIAK, I. (2007): Z badań nad wykorzystaniem alternatywnych surowców lignocelulozowych do produkcji płyt wiórowych [From the investigations on the utilization of the alternative lignocellulose raw materials to particleboards production] [in Polish] in Technologia Drewna Wczoraj, Dziś i Jutro, Wood Technology Institute, Poznań, Poland: 285–294
11. KONTEK, W.; ŁAWNICZAK, I. (1959): Możliwość wykorzystania słomy rzepakowej jako domieszki w produkcji płyt izolacyjnych [The possibility of the rape straw utilization as an admixture in isolation boards production] [in Polish], Przemysł Drzewny 10: 16–18
12. MORZE, Z.; PRĄDZYŃSKI, W. (1971): Możliwości wykorzystania odpadów wikliny do produkcji płyt wiórowych [The possibilities of the utilization of the wicker wastes to particleboards production] [in Polish], Rocz. WSR w Poznaniu, R I.II: 73–86
13. PAŁUBICKI, B.; ŁĘCKA, J.; DZIURKA, D. (2003): Influence of rape straw addend to pine particles on properties of particleboards, Ann. Warsaw Agricult. Univ. – SGGW, For. a. Wood Technol. 53: 276
14. PN-EN 826:1998 Thermal insulating products for building applications – determination of compression behaviour
15. WARMBIER, K., WILCZYŃSKI, A., AND DANECKI, L. (2013): Properties of one-layer experimental particleboards from willow (*Salix Viminalis*) and industrial wood particles, European Journal of Wood and Wood Products, 71(1), 25–28. DOI: 10.1007/s00107-012-0650-7

ACKNOWLEDGEMENT
Some of the mentioned tests were completed within the activity of Student Furniture Research Group (Koło Naukowe Meblarstwa), Faculty of Wood Technology, Warsaw University of Life Sciences – SGGW.

Streszczenie: Odnotowuje się systematyczny wzrost wykorzystania odpadów drzewnych jako surowca do produkcji płyt wiórowych, ale w obliczu rosnącego popytu na płyty wiórowe działania te są niewystarczające. W związku z tym pojawia się konieczność stosowania materiałów, których zasoby są odnawialne łatwiej (szybciej) niż zasoby leśne. Takimi materiałami mogą być: wierzba „energetyczna" (*Salix Viminalis* L.) i słoma rzepakowa. W przypadku wierzby dość często jej potencjał produkcyjny nie może być w pełni wykorzystany w sposób „energetyczny" ze względu na wymagania i możliwości konsumentów. W przypadku słomy rzepakowej, która bardzo często jest traktowana jako odpad (w bardziej optymistycznych scenariuszach – jako produkt uboczny) w produkcji

rolnej, wiadomo, że ilość tego surowca wzrasta ze względu na regulacje unijne dotyczące biopaliw. Obecnie tylko 2–3% słomy rzepakowej jest wykorzystywane do celów przemysłowych. Wyniki badań wskazują, że odpowiednie przygotowanie wymienionego alternatywnego surowca oraz dostosowanie parametrów technologicznych daje możliwość produkcji płyt wiórowych o parametrach równych lub nawet wyższych niż typowe płyty dostępne w handlu. Badania potwierdziły możliwość zastąpienia przemysłowych wiórów drzewnych cząstkami słomy rzepakowej nawet w 50% bez istotnego pogorszenia właściwości produkowanych płyt. Obiecujące są również parametry wytrzymałościowe i termoizolacyjne płyt o obniżonej gęstości, wykonanych z cząstek wierzby *Salix Viminalis* L.

Corresponding author:

Grzegorz Kowaluk
Nowoursynowska Str. 159
02-787 Warszawa, Poland
email: grzegorz_kowaluk@sggw.edu.pl