Annals of Warsaw University of Life Sciences - SGGW
Forestry and Wood Technology № 85, 2014: 49-52
(Ann. WULS - SGGW, For. and Wood Technol. 85, 2014)

Rape straw-wood particleboards resinated with UF resin and supplemented with nano-SiO_2

DOROTA DUKARSKA, ADAM DERKOWSKI
Department of Wood-Based Materials, Poznan University of Life Sciences

Abstract: *Rape straw-wood particleboards resinated with UF resin and supplemented with nano-SiO_2.* The presented study investigated the usability of nano-SiO_2 in the process of increasing the share of particles derived from annual plant waste in the wood chip boards resinated with UF resin. Experimental boards were manufactured with different share of rape straw particles (0-60%) and with or without the addition of nano-SiO_2 to UF resin. The study showed that an addition of nano silica to the resin allowed for either increasing the substitution of wood chips by up to 20%, or manufacturing boards of the same substitution degree as those without nano-SiO_2, but with improved mechanical properties. Therefore, these boards may be classified as P2 boards, intended for interior decoration and furniture used in dry conditions.

Key words: particleboard, rape straw, nano-SiO_2, substitution

INTRODUCTION

Long-term studies on the substitution of wood chips with annual plant waste demonstrated a reduced strength and water resistance of such boards, in a manner proportional to the substitution degree (Pałubicki et al. 2003). It was found that production of the boards supplemented with this raw material, loaded with urea-formaldehyde resin, and meeting the requirements of EN 312 standard required greater loading or limiting the substitution degree (Dziurka et al. 2005; Dukarska et al. 2006). Research conducted by Dukarska (2103) indicated the possibility of improving the mechanical properties of straw-containing boards. The author showed that supplementing the urea-formaldehyde (UH) resin with small amounts of nano-SiO_2 - (1.0-1.5%/100 g dry mass of the resin) resulted in significantly higher internal bond, modulus of elasticity, and rigidity of the boards made exclusively from rape straw particles. This was due to e.g. enhanced bond strength of the resin containing nano-SiO_2 (Lin et al. 2006; Roumeli et al. 2012). An addition of nano silica to UF resin improved also a hygiene class of the boards by limiting free formaldehyde content. With the above findings in mind, a research study was carried out with the aim of testing the suitability of using nano-SiO_2 to increase the substitution of wood chips with particles of annual plant waste in the manufacture of straw and wood chip boards loaded with UF resin and intended for general use and for interior decoration, including furniture used in dry conditions.

MATERIALS AND METHODS

Single layer experimental boards were made of pine wood chips and rape straw particles. The boards were loaded with urea-formaldehyde (UF) resin with the following parameters: dry resin solids – 64.4%, density - 1.285 g cm^{-3}, miscibility with water – 1.7, viscosity – 720 mPa s, gelation time at 100°C – 105 s, pH – 8.1. The hydrophilous fumed silica (nano-SiO2) with specific surface 200±25 m^2/g was added to the resin in the amount of 1.5% per 100 g of dry resin solids. The methods for the modification of silica surface with aminosilane and the preparation of the adhesive mixture were described by Domka et. al (1996) and Dukarska (2013).

Straw and wood chip boards with the assumed density of 700 kg/m^3 and the thickness of 12 mm were manufactured in the following conditions:

- pressing time 22 s/mm board thickness

- unit pressure 2.5 N/mm^2
- temperature 200º C
- resination rate – 12 %

The degree of wood chip substitution with rape straw particles was: 0, 10, 20, 30, 40, and 60%.

After a 7-day conditioning period, the following properties of the experimental boards were determined:

- modulus of rupture (MOR) and modulus of elasticity (MOE) according to EN 310
- internal bond (IB) according to EN 319
- swelling in thickness after 24 h soaking in water (Gt) according to EN 317
- formaldehyde content using the perforation test according to EN 120

The boards resinated with UF resin without the addition of nano-SiO_2 were used as a reference while analyzing the results.

RESULTS

Physical and mechanical properties of straw and wood chip boards, with different degree of wood chip substitution, supplemented and non-supplemented with nano-SiO_2 are presented in Table 1. As previously demonstrated in the studies on substituting wood chips with particles of annual plant waste, increased share of waste particles in the wood chip boards resulted in gradual reduction of the board internal bond (Dukarska et al. 2011, Dukarska and Dziurka 2012). However, an analysis of the study results showed that supplementing UF resin with nano silica in the amount of 1.5% of the resin dry mass allowed for the production of straw-wood chip boards with better mechanical properties than the corresponding boards without the addition of nano silica. The boards containing up to 40% of rape straw particles loaded with nano silica-free UF resin met the requirements of EN 312 standard for the general purpose P1 boards, concerning internal bond and bending strength. When the resin was supplemented with nano-SiO_2, the substitution degree increased up to 60% and the boards still met the requirements of the above-mentioned standard. It is worth mentioning that mechanical properties of the boards with 50% share of straw particles were typical for P2 boards, i.e., the boards intended for interior decoration, including furniture used in dry conditions. The data in Table 1 also show that, irrespective of the degree of wood chip substitution with straw particles, the use of nano silica slightly improved bending strength and rigidity of straw and wood chip boards.

Similarly as in the previous study (Dukarska 2013), supplementing the UF resin with nano-SiO_2 resulted in increased swelling of the boards, as compared with those without nano-SiO_2 addition. The changes were particularly significant in boards with 50% and 60% share of straw particles. Their swelling increase was about 25% greater than in the reference boards. The resulting swelling values were relatively high and they significantly exceeded those specified in EN 312 standard for P2 boards. However, it should be emphasized that swelling of P2 boards is an additional parameter and its determination is not required. High values of the swelling parameter probably originated from the fact that the experimental boards were single layer ones and did not have an external layer limiting water penetration. Different effects of silica on water resistance and mechanical properties may indicate poorer adhesion of nano-SiO_2 supplemented UF resin to wood chips and straw particles, as compared to pure UF resin.

The studies conducted so far demonstrated that the use of annual plant waste slightly reduced the board formaldehyde content (Dukarska and Dziurka 2012). An analysis of the hygiene class of the experimental boards showed further decrease in formaldehyde content in the boards loaded with nano-SiO_2-supplemented resin. In the boards containing 50% or 60% of straw particles and silica, the content of free formaldehyde was by about 25% lower than in

nano-SiO_2-free boards. This confirms the results of previous research reported in this field by Dukarska (2013), and may be important considering a global trend to produce boards characterized by low content or emission of formaldehyde.

Table 1. The properties of straw and wood chip boards depending on the degree of wood chip substitution and addition of nano-SiO_2 to UF resin.

Substitution degree	IB		MOR		MOE		G_t		mg CH_2O/100 g of board dry mass
%	N/mm^2						%		
Nano-SiO_2-free boards									
0	0.55	*0.06**	13.5	*1.27**	2340	*110**	20.72	*1.1*	8.09
10	0.56	*0.02*	13.5	*1.6*	2350	*120*	21.74	*1.8*	8.14
20	0.50	*0.04*	12.8	*2.0*	2300	*130*	22.47	*2.5*	7.45
30	0.41	*0.03*	12.8	*1.3*	2280	*97*	24.58	*4.0*	7.28
40	0.38	*0.05*	12.0	*1.4*	2220	*62*	29.13	*3.1*	6.90
50	0.26	*0.06*	12.5	*0.89*	2250	*98*	33.24	*2.7*	6.72
60	0.22	*0.02*	11.4	*1.1*	2130	*100*	37.58	*3.2*	6.28
Nano-SiO_2-supplemented boards									
0	0.68	*0.05*	15.2	*0.85*	2590	*99*	22.71	*1.7*	6.14
10	0.62	*0.03*	15.4	*0.78*	2510	*102*	24.26	*2.4*	6.02
20	0.55	*0.06*	14.5	*1.2*	2600	*130*	23.50	*3.4*	5.89
30	0.49	*0.01*	14.6	*1.0*	2530	*104*	29.76	*2.1*	5.33
40	0.44	*0.08*	13.9	*1.7*	2590	*56*	35.41	*1.7*	4.92
50	0.40	*0.03*	13.3	*0.99*	2600	*89*	41.11	*0.9*	5.04
60	0.28	*0.01*	12.8	*0.83*	2480	*99*	47.79	*2.3*	4.87

*standard deviation

CONCLUSIONS

In summary, it may be concluded that the addition of nano silica to UF resin enabled increasing the substitution of wood chips in P1 boards by 20%. The boards containing up to 50% of straw particles and loaded with nano-SiO_2-supplemented UF resin met the requirements concerning internal bond and modulus of elasticity for the boards intended for interior decoration, including furniture used in dry conditions.

REFERENCES

1. DOMKA L., KRYSZTAFKIEWICZ A., MARCINIEC B., GULIŃSKI J., URBANIAK W., 1996: Napełniacze krzemionkowe i krzemianowe modyfikowane krajowymi silanowymi związkami proadhezyjnymi. Przemysł Chemiczny 75/10; 376-378
2. 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); 12
3. DUKARSKA D., ŁĘCKA J., SZAFONI K., (2011): Straw of white mustard (Sinapis Alba) as an alternative raw material in the production of particle boards resinated with UF resin. Silv. Colendar. Rat. Ind. Lignar 10 (1): 21-28

4. DUKARSKA D., DZIURKA D., 2012: Raw materials and particleboards – a current status and perspectives. Part I. Chapter III. Plants potential alternative raw material for the production of particleboards.s.39-54. Publishing House WULS-SGGW
5. DUKARSKA D., 2013: The effect of an addition of nano-SiO_2 to urea resin on the properties of boards manufactured from rape straw. Ann. WULS-SGGW, For and Wood Technol. No 82, s. 242-245
6. 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);5
7. LIN Q., YANG G., LIU J., ROA J. 2006: Property of nano-SiO2/urea formaldehyde resin. Front For. China 2:230-237
8. ROUMELI E., PAPADOPOULOU E., PAVLIDOU E., VOURLIAS G., BIKIARIS D., PARASKEVOPOULOS K.M., CHRISSAFIS K., 2012: Synthesis. characterization and thermal analysis of urea-formaldehyde/nanoSiO_2 resin. Thermochimica Acta 527; 33-39
9. PAŁUBICKI B., ŁĘCKA J., DZIURKA D., 2003: Influence of rape straw addend to pine particles on properties of particleboards". Ann. Warsaw Agricult. Univ.-SGGW. Forestry and Wood Technology 53; 276-278

Streszczenie: *Płyty rzepakowo – wiórowe zaklejone żywicą UF z dodatkiem nano-SiO_2.* W prezentowanej pracy zbadano możliwość zastosowania nano-SiO_2 celem zwiększenia stopnia substytucji wiórów drzewnych cząstkami odpadów roślin jednorocznych w procesie wytwarzania płyt słomowo - wiórowych zaklejonych żywicą UF. W ramach pracy wytworzono płyty o zróżnicowanym stopniu substytucji wiórów drzewnych cząstkami słomy rzepakowej (0-60%) z i bez dodatku nano-SiO_2 do żywicy UF. Na podstawie przeprowadzonych badań stwierdzono, iż dodatek nanokrzemionki do żywicy klejowej pozwala na zwiększenie stopnia substytucji wiórów drzewnych nawet o 20% bądź wytworzenie płyt o tym samym stopniu substytucji co płyty bez dodatku nano-SiO_2, jednakże o wyższych parametrach wytrzymałościowych. Pozwala to na zakwalifikowanie ich do płyt typu P2 stosowanych do wyposażeń wnętrz, łącznie z meblami użytkowanych w warunkach suchych.

Corresponding author:

Poznań University of Life Sciences
Department of Wood-Based Materials
Wojska Polskiego 38/42
60-627 Poznań.
Poland
e-mail: ddukar@au.poznan.pl