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IMPACT OF PRESSING TEMPERATURE ON PHYSICAL AND MECHANICAL PROPERTIES OF PANELS MADE FROM PARTICLES OF RASPBERRY STEMS (*RUBUS IDAEUS* L.) AND GRAPE PRUNING RESIDUES (*VITIS VINIFERA* L.)

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ABSTRACT

The researches in the paper are directed to creating possibilities for production of particleboards on the basis of raw material form lignocellulosic agricultural residues, as well as to establish the impact of pressing temperature on physical and mechanical properties of particleboards.

Experimental three-layer particleboards from two types of particles (raspberry stems and grape pruning residues) were made in laboratory condition.

Water-soluble phenol-formaldehyde resin was used for particle bonding.

Panels' pressing temperature ranged from 150 to 190ºC.

The research results showed that increment of pressing temperature to certain extent has positive effect on physical and mechanical properties of the panels, i.e., water absorption and thickness swelling decrease, while bending strength and internal bond of the panel increase.

Key words: pressing temperature, lignocellulosic agricultural residues, raspberry stems, grape pruning residues, particleboards, physical properties, mechanical properties.

1. INTRODUCTION

Particleboards are one of the most significant types of wood-based panels. Good properties of these panels, their easy processing, large format and other good features contribute to their wide application in furniture production, construction and other areas of application.

Intensive growth of world population brings on an increased demand for wood and wood-based panels. The demand for different types of wood-based panels leads to search for new sources of raw materials for production of these panels, as an alternative to forest wood mass, which is still a basic raw material for wood-based panel production.

In the last few decades particleboard industry has shown an intensive development. Besides forest wood raw material for particleboard production, there are researches for utilization of wide range of lignocellulosic agricultural residues as a substitute for basic forest wood raw material. Agricultural residues are numerous, they are renewable, widely spread and easily accessible. Beside their wide distribution and renewability, utilization of agricultural residues is also an advantage for a country's economy, its environment and development of their processing technologies.

The attention of the researchers from different world regions is oriented to studying lignocellulosic agricultural residues as a raw material for particleboard production, considering it as one of the solutions for its rational utilization. The researchers have worked with various plants from different world regions such as: rice husk (Ayrilmis *et al.* 2012; Iliev *et al.* 2005; Kwon *et al.* 2013), sunflower stems (Guler *et al.* 2006; Mihailova *et al.* 2008), can stems (García-Ortuño *et al.* 2011, Ghalehno *et al*. 2010; Kord *et al*. 2015), bagasse (Garzón *et al.* 2012; Ghalehno *et al.* 2013; Mendes *et* *al.* 2009), bamboo stalks (Papadopoulos *et al.* 2004), cotton stalks (Guler *et al.* 2004; Mihailova *et al.* 2006; Mihailova *et al.* 2008), pepper stems (Guntekin *et al.* 2008), grape pruning residues (Gürüler *et al.* 2015; Iliev *et al.* 2005; Mihajlova *et al.* 2007; Yeniocak *et al.* 2014; Yossifov *et al.* 2001), poppy stems (Iliev *et al.* 2005), flax shives (Mihajlova *et al.* 2007; Mihailova *et al.* 2008), raspberry stems (Mihailova *et al.* 2008; Todorov *et al.* 2007), tobacco stems (Mihailova *et al.* 2009), rice straw (Yang *et al.* 2003).

The positive scientific knowledge in this field contributes to treatment of agricultural residues as raw material for further processing, i.e., as a possible raw material for particleboard production. Regarding their anatomical and chemical composition, lignocellulosic agricultural residues are similar to wood, and with appropriate technological conditions for their utilization as material for particleboard production, they will be effective alternative resource.

The Republic of Bulgaria and The Republic of Macedonia have developed agriculture. Every year huge quantities of lignocellulosic residues are being obtained from the fields of these countries. These quantities are not rationally used, so they are a ballast to agriculture and in some cases are also pollutants of the environment. In these countries, grape pruning residues, fruit trees pruning's, sunflower stems, corn stems, tobacco stems, cotton stems, wheat straw, hemp and flax residues draw scientists' attention as lignocellulosic agricultural residues. Accordingly, these residues should be considered as raw material that could be utilized in particleboard production in both countries.

From technological point of view, pressing temperature is an important technological factor in particleboard production. In addition, the impact of pressing temperature on particleboard characteristics is of a great significance. The impact of this technological factor in particleboard production has been insufficiently studied. Therefore, in this paper the researches are directed to investigation of the impact of pressing temperature on the properties of three-layer particleboards made from lignocellulosic agricultural residues, i.e., from raspberry stems and grape pruning residues.

2. METHOD OF THE EXPERIMENTAL WORK

The aim of the research presented in the paper is to produce panels from two types of particles from agricultural residues – raspberry stems and grape vine pruning residues – and to trace the impact of pressing temperature on physical and mechanical properties of these panels.

Two types of three-layer particleboards – panels made from raspberry stems particles (panels TP-M) and panels made from particles of grape pruning residues (panels TP-L) – were made in laboratory at the Department of Mechanical Wood Processing at the University of Forestry in Sofia. Surface layers of the panels were made with particles from the fraction 2,5/1,5, while the core layer from the fraction 4/2,5. The ratio of the surface layer and core layer was 40:60, moisture content of the lignocellulosic particles of 8%, type of the adhesive was water-soluble phenol formaldehyde resin with initial concentration of 55% and work concentration of 45%, dimensions of the panels of 500×500×16 mm and moisture content of the panels of 8%. The density of the panels ranged within 500 to 900 kg/m^3, participation of the glue from 8 to 16% and pressing temperature from 150 to 190°C.

Seventeen panels from each type of lignocellulosic agricultural residues were made in accordance with the experimental matrix shown in table 1.

After production, the laboratory made panels were left for acclimatization for a period of 24 hours, after which adequate test specimens were cut in accordance with the valid European norms for testing of the physical and mechanical properties of the panels. Eight test specimens from each panel were cut.

Sampling and cutting of the test specimens for testing the physical and mechanical properties of the panels was made in accordance with the standard BDS EN 326-1, and determination of the dimensions of test specimens according to BDS EN 325. Physical and mechanical properties of the panels were determined in accordance with the relevant test methods specified in the European norms.

Before testing, the test specimens were conditioned to constant mass in an atmosphere with a relative humidity of 65±5% and temperature of 20±2ºC.

The following properties of the panels were tested: water absorption and thickness swelling according to BDS EN 317, bending strength according to BDS EN 310 and tensile strength perpendicular to the plane of the panels (internal bond) according to EN 319.

For each tested property of each panel, the following variation-statistical coefficients were calculated: mean arithmetical value (X_{mean}), standard deviation (S_x), coefficient of variation (V_x), error of the mean arithmetical value (m_x) and the index of correctness (P_x).

Table 1. *Experimental matrix*

Panel number	ρ, kg/m^3	Resin participation (Rp), %	Pressing parameters		
			τ, min/mm	P, MPa	T, °C
1	500	12	0,75	$P_{initial}$ - 2,4 P_{mean} - 1,2 P_{end} - 0,6	170
2	600				
3	700				
4	800				
5	900				
6	700	8	0,75	$P_{initial}$ - 2,4 P_{mean} - 1,2 P_{end} - 0,6	170
7		10			
8		14			
9		16			
10	700	12	0,55	$P_{initial}$ - 2,4 P_{mean} - 1,2 P_{end} - 0,6	170
11			0,65		
12			0,85		
13			0,95		
14	700	12	0,75	$P_{initial}$ - 2,4 P_{mean} - 1,2 P_{end} - 0,6	150
15					160
16					180
17					190

3. RESULTS FROM THE EXPERIMENTAL RESEARCH

The impact of pressing temperature on physical and mechanical properties of three-layer particleboards made from raspberry stems (TP-M) and grape pruning residues (TP-L) can be seen from the data given in table 2 (for water absorption), table 3 (for thickness swelling), table 4 (for bending strength) and table 5 (for internal bond).

Table 2. *Water absorption of three-layer particleboards made from raspberry stems (TP-M) and grape pruning residues (TP-L) at different pressing temperatures*

T, °C	Panels type TP-M					Panels type TP-L				
	X_{mean}, %	S_x, %	m_x, %	V_x, %	P_x, %	X_{mean}, %	S_x, %	m_x, %	V_x, %	P_x, %
150	49	19,1	6,0	39,4	1,2	50	3,6	1,3	13,6	4,5
160	73	14,5	4,6	28,1	3,8	72	3,8	1,4	14,3	4,9
170	67	12,3	3,9	24,5	3,6	67	1,3	0,7	10,3	3,6
180	52	13,7	4,3	19,7	2,6	54	2,9	1,0	13,0	4,6
190	57	22,0	6,9	35,8	3,3	57	3,8	1,4	13,2	4,7

Table 3. *Thickness swelling of three-layer particleboards made from raspberry stems (TP-M) and grape pruning residues (TP-L) at different pressing temperatures*

T, °C	Panels type TP-M					Panels type TP-L				
	X_{mean}, %	S_x, %	m_x, %	V_x, %	P_x, %	X_{mean}, %	S_x, %	m_x, %	V_x, %	P_x, %
150	27,4	4,9	1,6	31,2	4,5	26,7	12,8	4,6	13,2	4,9
160	25,8	3,4	1,1	20,3	3,8	24,6	15,5	5,5	12,4	4,6
170	19,0	4,8	1,5	27,2	3,9	19,1	11,6	4,1	14,5	4,8
180	20,6	1,0	0,3	5,5	1,7	22,4	11,1	3,9	13,9	4,3
190	29,8	4,2	1,3	24,3	2,8	28,8	11,6	4,0	13,5	4,1

Table 4. *Bending strength of three-layer particleboards made from raspberry stems (TP-M) and grape pruning residues (TP-L) at different pressing temperatures*

T, °C	Panels type TP-M					Panels type TP-L				
	X_{mean}, N/mm^2	S_x, N/mm^2	m_x, N/mm^2	V_x, %	P_x, %	X_{mean}, N/mm^2	S_x, N/mm^2	m_x, N/mm^2	V_x, %	P_x, %
150	13	1,9	0,59	14,2	4,4	15	3,4	1,1	16,0	4,9
160	17	3,0	0,95	22,8	3,1	17	5,8	1,8	12,5	3,1
170	18	4,5	1,4	25,2	2,9	18	2,8	0,9	14,1	4,7
180	16	1,4	0,43	11,4	3,5	17	3,1	1,2	14,8	4,5
190	14	1,9	0,62	15,9	4,8	16	5,4	1,7	14,7	4,9

Table 5. *Tensile strength perpendicular to the plane of the panels of three-layer particleboards made from raspberry stems (TP-M) and grape pruning residues (TP-L) at different pressing temperatures*

T, °C	Panels type TP-M					Panels type TP-L				
	X_{mean}, N/mm^2	S_x, N/mm^2	m_x, N/mm^2	V_x, %	P_x, %	X_{mean}, N/mm^2	S_x, N/mm^2	m_x, N/mm^2	V_x, %	P_x, %
150	0,62	0,10	0,03	16,7	2,3	0,26	0,28	0,12	11,3	1,1
160	0,73	0,19	0,06	23,5	4,8	0,33	0,14	0,05	15,9	4,9
170	0,80	0,06	0,02	8,0	2,5	0,48	0,13	0,04	14,5	4,5
180	0,98	0,19	0,06	26,8	4,5	0,65	0,10	0,05	15,8	4,9
190	0,92	0,16	0,05	21,6	4,3	0,54	0,75	0,06	15,3	4,3

The impact of increment of pressing temperature on water absorption of the panels can be seen from the data given in table 2 and in figure 1. The increment of pressing temperature in range of 150ºC to 160ºC causes growth in the values of water absorption in both types of panels. The increment of pressing temperature in range of 170ºC to 180ºC causes drop in the values of water absorption in both panel types, while at pressing temperature of 190ºC, the values of this property rise again.

The lowest values of water absorption are obtained at the lowest pressing temperature of 150ºC, i.e. 49% in panels type TP-M and 50 % in panels type TP-L.

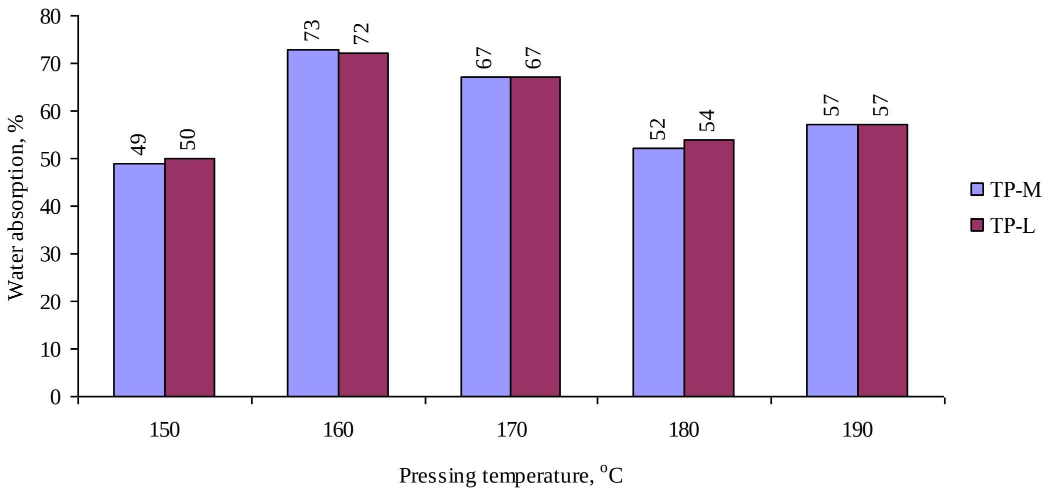

Figure 1. *Water absorption of panels type TP-M and TP-L at different pressing temperatures*

The relation between thickness swelling and pressing temperature of the panels can be seen from the data given in table 3, as well as in figure 2. As we can see from the data, increment of pressing temperature in range of 150ºC to 170ºC causes decrement of the thickness swelling of two types of panels. Increment of pressing temperature in range of 180ºC to 190ºC leads to an increase in the values of this property in both types of panels.

The lowest values of thickness swelling in both types of panels were obtained at pressing temperature of 170ºC, i.e. 19,0% for panels type TP-M and 19,1% for panels type TP-L.

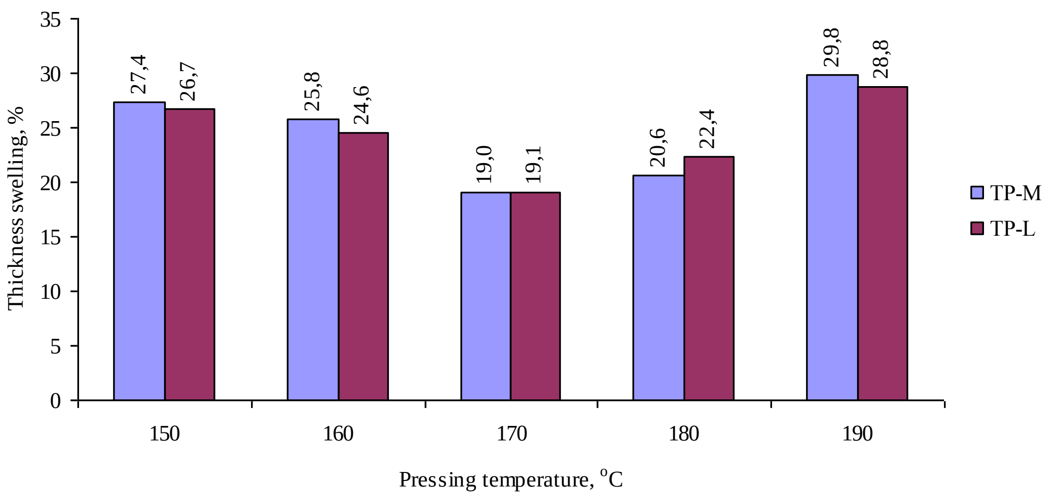

Figure 2. *Thickness swelling of panels type TP-M and TP-L at different pressing temperatures*

The data for bending strength and the impact of the pressing temperature on the values of this mechanical property are shown in table 4 and in figure 3. The data indicate that increment of the pressing temperature in the range of 150ºC to 170ºC causes rise in the values of the bending strength in both types of panels, while with increment of pressing temperature in range of 180ºC to 190ºC a decrease of the values of this property was noticed in both panel types. Regarding the values of bending strength, the best pressing temperature for both panel types was 170ºC, which ensure the highest values of this property (18 N/mm^2).

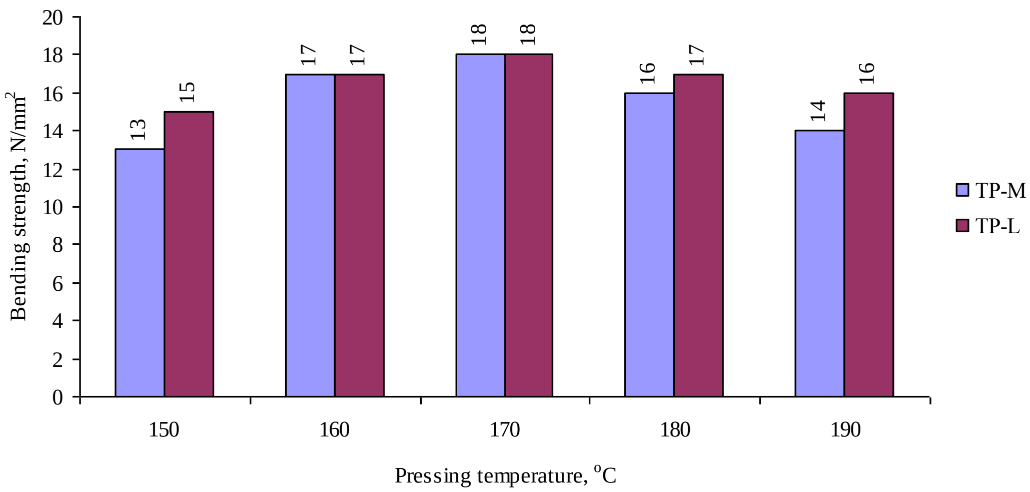

Figure 3. *Bending strength of panels type TP-M and TP-L at different pressing temperatures*

Tensile strength perpendicular to the plane of the panel (internal bond) increases with rise in the pressing temperature, as it can be seen from the results given in table 5 and in figure 4. The increment of pressing temperature in range of 150ºC to 180ºC causes an increase of the values of the internal bond in both types of panels, while at pressing temperature of 190ºC, the values of this property in both panel types decrease. In both panel types, the highest values were obtained at pressing temperature of 180°C, i.e. 0,98 N/mm^2 in panels made from raspberry stems and 0,65 N/mm^2 in panels made from grape pruning residues. The values obtained were also good at pressing temperature of 170ºC, whereas the internal bond of panel made from raspberry stems and from grape pruning residues was 0,80 N/mm^2 and 0,48 N/mm^2 respectively. At pressing temperature of 190°C, the values of internal bond in both panel types were also good, whereas the internal bond of panel made from raspberry stems and of panel made from grape pruning residues. was 0,92 N/mm^2 and 0,54 N/mm^2 respectively

In general, the values of this property were higher in panels made from particles of raspberry stems.

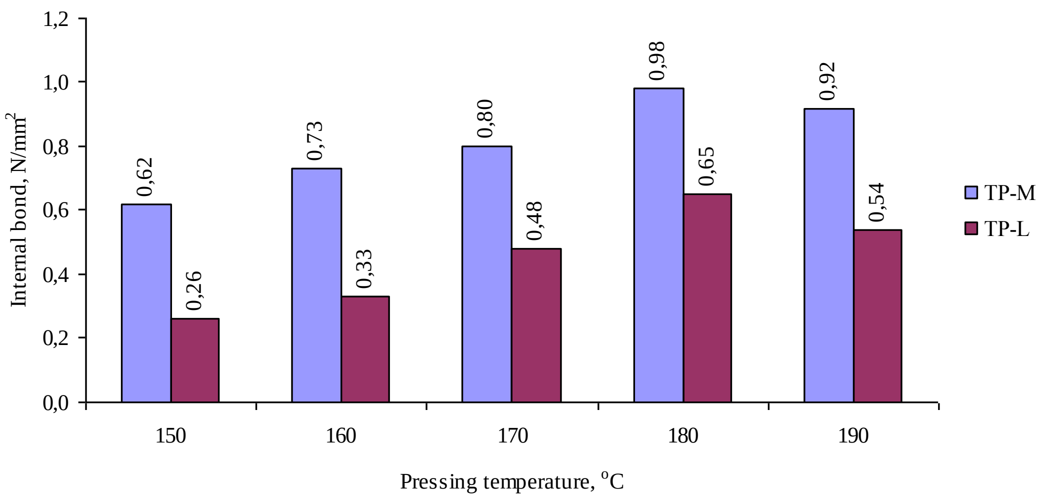

Figure 4. *Internal bond of panels type TP-M and TP-L at different pressing temperatures*

4. CONCLUSIONS

As a result of the researches and on the basis of the analysis of the results obtained, the following major conclusions can be drawn:

1. Utilization of raspberry stems and grape pruning residues as lignocellulosic agricultural raw material for wood based panels' production does not cause technological difficulties, apart from the necessity of providing areas for storage and preservation due to seasonal picking up.
2. Increment of pressing temperature to some extent has positive effect on physical and mechanical properties of the panels: water absorption and thickness swelling decrease, whereas bending strength and internal bond increase.
3. Regarding pressing temperature, the best results for particular panel's property are obtained at temperature of 150ºC for water absorption, at 170ºC for thickness swelling and bending strength and at 180ºC for internal bond.
4. For manufacture of panels made from particles of raspberry stems and grape pruning residues on the basis of phenol-formaldehyde resin, a pressing temperature of 180ºC can be selected as a compromising option.
5. The good properties of the panels made from particles of raspberry stems and grape pruning residues, as well as the relatively low price of this raw material, predetermines the competitiveness of these panels for different areas of application.
6. Raspberry stems and grape pruning residues represent a quality raw material from lignocellulosic agricultural residues for panels' production, and this raw material can be recommended for industrial production of this type of wood-based panels.

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