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IMPROVING MECHANICAL AND PHYSICAL PROPERTIES OF PARTICLEBOARD MADE FROM VINE (*VITIS VINIFERA* L.) PRUNINGS BY ADDITION REINFORCEMENT MATERIALS

Mehmet Yeniocak, Osman Goktas, Ertan Ozen, Ahmet Gecgel
Mugla Sitki Kocman University, Faculty of Technology
Department of Woodworking Industrial Engineering
Mugla, Turkey

Ahmet Gecgel
Orge Yapi Tasarim A.Ş.
Aydin, Turkey

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ABSTRACT

The main goal of this study was to improve mechanical and physical properties of particleboards made from vine (*Vitis vinifera* L.) prunings by addition of reinforcement materials. In Turkey, there are 462.000 hectare areas for vine cultivation. Annually, approximately 2.345.000 ton vine pruning parts residues are remained. Every season, large quantities of vine prunings are left as by-products in the fields, and unfortunately they are not utilized properly by the related industries. In this study, vine prunings and particles were used as raw material for three-layer flat pressed particleboards. Cord fabric fibre (CFF) (mixed), Cord fabric (CF) (sandwiched), plaster mesh (PM) (sandwiched), polyester fibre (PF) (sandwiched) were used as reinforcement materials. A commercial urea-formaldehyde (UF) resin was used as binder. Small size experimental panels (56x56x2 cm) were manufactured. Some physical properties (like, thickness swelling (TS), density, moisture content (MC) and mechanical properties (like, modulus of rupture (MOR), modulus of elasticity (MOE), internal bond (IB) perpendicular screw-holding (PSH, ⊥), lateral screw-holding strengths (SHS, //), and tensile strength parallel to surface properties of panels were determined. The results indicated that some properties of the reinforced panels can give satisfactory values compared to control (non reinforcement) panels. Generally the reinforcement materials increased the mechanical properties of the particleboards. Such particleboards can meet the standards for isolation panels and interior-use.

KEYWORDS: Particleboard, vine pruning, reinforcement, mechanical properties.

INTRODUCTION

Increasing social demands for various wood products and especially wood-based panels leads to the continuous effort for finding new wood resources as an alternative to forest wood (Ntalos and Grigoriou 2002). Researches have been conducted by both industry and research institutions to find this alternative materials (Nasser et al. 2011). Agricultural residues are raw materials of renewable resources that can be utilized in wood industry (Almeida et al. 2002, Olorunnisola 2008). These alternative raw materials, can play a major role in the future of particleboard industry (Ghalehno et al. 2013).

Some studies on particleboard of wood and agricultural residues include cotton stalks (Guler and Ozen 2004), jose tall wheatgrass (Zheng et al. 2007), hazelnut husk (Copur et al. 2007), kenaf (Grigoriou et al. 2000, Kalaycioglu and Nemli 2006), corn pith (Wang and Sun 2002), sunflower stalks (Bektas et al. 2005), betel palm (Lin et al. 2008), soybean husk (Pandey and Nema 2004), cotton carpel (Alma et al. 2005), redcedar (Hiziroglu and Holmcomb 2005), mimosa bark (Nemli and Colakoglu 2005), oil palm trunk (Rokiah et al. 2010), giant reed (Garcia et al. 2011), willow (Warmbier et al. 2013), kiwi (Nemli et al. 2003), Bamboo (Papadopoulos et al. 2004), reed (Ghalehno and Nazerian 2011), roselle stalks (Ghalehno and Nazerian 2012), and bagasse (Xu et al. 2009, Youngquist et al. 1997).

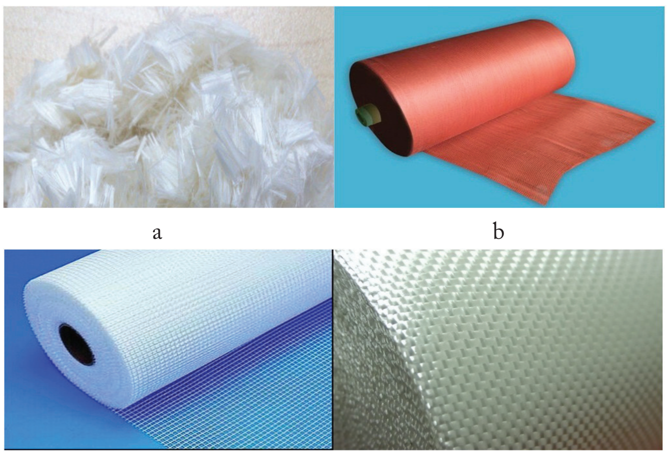
Vine prunings are abundant agricultural waste product in Turkey. Vine is a traditional crop cultivated for its fruit and the production of vine and covers large areas of land. After the pruning season, a large quantity of lignocelluloses material remains in the fields every year. The average pruning yield per hectare is about five tons (Ntalos and Grigoriou 2002) and there are currently 469.000 hectares (Tuik 2012) of grape vines cultivation. Annually, approximately 2,345.000 ton vine pruning parts residues remain on the fields. Part of the pruning waste is used as fuel, but large quantities remain unused in the fields, thus vine pruning wastes are considered as an economic loss.

In the last decade, research has been carried out on vine pruning waste. For example, Ntalos and Grigoriou (2002) and Yeniocak et al. (2014), have studied the suitability of vine pruning material for particleboard production. Unfortunately, they reported poor physical and mechanical properties compared to industrial particle boards. Therefore, the objective of this study was to improve the physical and mechanical properties of three-layer particleboards manufactured by using various reinforcement materials like cord fabric fibre (CFF), cord fabric (CF), plaster mesh (PM) and polyester fibre (PF).

MATERIAL AND METHODS

As raw materials for this study are consisted vine pruning (VP) (*Vitis vinifera* L. cv. *Sultani*), cord fabric (in density 250, 570 and 890 g.m^{-2}), plaster mesh (in porous 2x2, 7x7 and 15x 15 mm), cord fabric fibre and polyester fibre. Vine prunings were collected from Manisa / Sarıgol region in Turkey. The vine pruning stalks were chipped by a universal chipper then the particles were dried to 3 % moisture content. Dusts in the chips were removed by an electrical fan. Prior to blending, vine pruning and industrial wood particles were screened by a screening apparatus through meshes with 3, 1.5 and 0.8 mm apertures to remove oversize and undersize particles and separate the core and surface layer particles (Nemli et al. 2004). No water-repelling agent was used during the board construction. The mat configuration was three-layer and formed by manual distribution after adhesive application in blender. The proportion was 35 for surface and 65 % for core layer.

A commercial liquid UF-resin that was purchased from the local supplier was used. The UF-resin was applied to particles by spraying into a rotating drum that designed and built for this study. Based on oven dry particle weight, 8 and 10 % UF-resin was applied to the face and core layers, respectively. The mat configuration was formed by hand distribution in a template after resin application. Two methods were used in order to reinforce the particle boards. In the first method (Sandwich) materials of CF, PM and PF (Fig. 1) were located between surface and core layers during the configuration (Fig. 2). In the second method (Mixed) materials of CFF (Fig. 1) were cut in pieces of around 30 mm long and were mixed with chips of vine pruning more compact on surface layer (Fig. 3). After the mat was pre-pressed the template was removed and the pressing process was started. The particleboards were pressed at a maximum pressure of 25 kg.cm^{-2}, at 150°C, for 7 min. The target dimensions of panels were 56x56x2 cm and density for all board types was 0.70 g.cm^{-3}. Nine different panel models were prepared and for each model (Tab. 1), four experimental panels were manufactured. After pressing, panels were conditioned at a temperature of 20°C and 65 % relative humidity, edge trimmed to 55x55 cm. Totally 36 panels, four for each combination were produced.



a b

c d

a) Cord fabric fibre, b) Cord fabric, c) Plaster mesh, d) Polyester fabric fibre.

Fig. 1: Reinforcement materials used in the study.

Tab. 1: Experimental design and composition of three-layer particleboards of vine prunings.

Board Type	Reinforcement material	Reinforcement method	Adhesive (%)		Proportion (%)	
			Surface	Middle	Surface	Middle
A	CFF	Mixed	10	8	35	65
B	CF 250 g.m^{-2}	Sandwiched	10	8	35	65
C	CF 570 g.m^{-2}	Sandwiched	10	8	35	65
D	CF 890 g.m^{-2}	Sandwiched	10	8	35	65
E	PM 2x2 mm	Sandwiched	10	8	35	65
F	PM 7x7 mm	Sandwiched	10	8	35	65
G	PM 15x15 mm	Sandwiched	10	8	35	65
H	PF	Sandwiched	10	8	35	65

K	Control (100 % vine prunings)	----	10	8	35	65

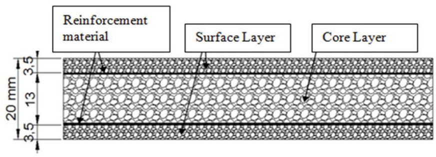


Fig. 2: CF, PM and PF sandwiched between layers.

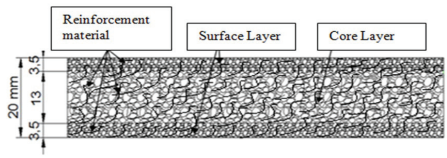


Fig. 3: CFF materials mixed with chips of vine pruning.

Testing of the samples

Test samples were cut from the boards and the following properties were determined in accordance with appropriate European standards: density (EN 323 1999) thickness swelling (TS) (EN 317 1993), moisture content (MC) (EN 322 1992), static bending (modulus of rupture) (MOR), modulus of elasticity (MOE) (EN 310 1999) internal bond (IB) (EN 319 1993) tensile strength parallel to surface (TSP) (ASTM 1037 1996), perpendicular screw holding strength (PSH) and lateral screw holding strength (LSH) (TS EN 320 2011). All results were statistically analyzed by using the analysis of variance (ANOVA) and Tukey's mean separation tests.

RESULTS

Tabs. 2 and 3 show the test results for the samples. The density was ranged from 0.517 to 0.719 g.cm^{-3}. All of reinforcement materials (except CFF) were proved density of particleboard compared with control group.

According to the standard EN 312 (2005) particleboards should have a maximum TS value of 14 % for 24 h immersions in water. The average TS of the produced particleboards was ranging from 12.51 to 30.84 % after immersion in the water for 24 h. The TS values were increasing with decreasing the board density. PF, all of PM's, CF (570), and CF (890 g.m^{-2}) decreased the TS of particleboard compared with the control group.

The MC was ranged from 9.21 to 10.56 %. The reinforcement materials increased the MC of particleboards compared with the control group.

The average values of mechanical properties (MOR, MOE, IB and SHS) are given in Tab. 3. Based on EN standards, 11.5 and 13 N.mm^{-2} are the minimum requirements for MOR of particleboards for general uses and furniture respectively (EN 312 2005). The values of MOR were between 3.573 to 13.602 N.mm^{-2}.

The MOE values of experimental panels ranged from 566.86 to 2096.14 N.mm^{-2}. Reinforcement materials supported the experimental panels on MOE properties between 9 and 270 % compared to control group. Panel E and G (reinforced by PM) showed the best performance on elasticity.

The perpendicular IB strength values obtained were ranging from 0.064 to 0.498 N.mm^{-2}. According to the EN 312 (2005) standard the minimum requirements for perpendicular IB strength values of particleboards for general uses is 0.350 and for furniture it is 0.450 N.mm^{-2}. Particleboard types E and G (reinforced by PM) had IB values that met the requirements panels of load bearing.

Tab. 2: Physical properties of three-layer particleboard made from vine pruning particles.

Physical properties	Board type	N	Mean	S.D.^{w}	S.E.^{x}	X min^y	X max^z	p
Density (g .cm^{-3})	A	10	0.517^b	0.052	0.017	0.480	0.554	*
	B	10	0.633^{ab}	0.019	0.006	0.619	0.647	
	C	10	0.719^a	0.026	0.008	0.701	0.737	
	D	10	0.651^{ab}	0.024	0.008	0.634	0.668	
	E	10	0.607^{ab}	0.018	0.006	0.594	0.620	
	F	10	0.628^{ab}	0.037	0.012	0.602	0.654	
	G	10	0.738.^{a}	0.032	0.004	0.503	0.973	
	H	10	0.663^{ab}	0.040	0.013	0.634	0.692	
	K	10	0.607^{ab}	0.054	0.017	0.569	0.645	
Thickness swelling 24 h (%)	A	10	30.84^d	5.79	1.36	20.98	40.71	*
	B	10	18.04^{abc}	2.58	0.81	16.19	19.89	
	C	10	15.69^a	3.17	1.00	13.42	17.96	
	D	10	16.18^a	3.22	1.02	13.88	18.49	
	E	10	16.33^a	2.02	0.63	14.88	17.77	
	F	10	18.19^{abc}	1.58	0.50	17.05	19.32	
	G	10	13.01^a	1.39	0.44	12.01	14.01	
	H	10	12.51^a	7.93	2.50	6.84	18.18	
	K	10	17.11^{ab}	5.33	1.68	13.29	20.93	
Moisture content (%)	A	10	10.45^{ab}	1.45	0.57	8.53	12.34	*
	B	10	10.34^{ab}	2.34	0.45	9.56	11.67	
	C	10	9.67^a	2.96	0.69	8.85	10.32	
	D	10	9.54^a	1.56	0.84	7.89	10.84	
	E	10	9.38^a	1.82	0.92	8.92	10.74	
	F	10	10.25^{ab}	2.06	0.72	9.59	11.75	
	G	10	10.56^b	1.69	0.52	8.78	12.03	
	H	10	9.85^{ab}	0.87	0.23	7.34	10.87	
	K	10	9.21^a	1.52	0.47	7.41	9.62	

a,b,c,d, e values having the same letter are not significantly different and vice versa (for Tukey test)
w Standard deviation
x Sampling error
y Minimum value
z Maximum value
* Significance level of 0.05 (for ANOVA).

The tensile strength parallel to surface values were ranging from 0.901 to 5.491 N.mm^{-2}. Based on EN standard the minimum requirement for tensile strength parallel to surface is 3.5 N.mm^{-2}. Particleboard types E and nearly G (reinforced by PM) had TSP values that meet the requirements of panels for load bearing.

Tab. 3: Mechanical properties of three- layer particleboard made from vine pruning particles.

Mechanical properties $N.mm^{-2}$	Board type	N	Mean	S.D.[w]	S.E.[x]	X min[y]	X max[z]	p
Static bending (MOR)	A	10	3.599^{e}	1.213	0.384	2.731	4.467	
	B	10	9.605^{bc}	1.543	0.488	8.501	10.709	
	C	10	8.062^{c}	2.008	0.635	6.626	9.498	
	D	10	10.396^{b}	3.207	1.014	8.102	12.690	
	E	10	13.602^{a}	3.067	0.970	11.408	15.796	*
	F	10	7.245^{c}	1.126	0.356	6.440	8.050	
	G	10	12.516^{a}	6.539	2.068	7.838	17.194	
	H	10	6.814^{d}	1.051	0.332	6.062	7.566	
	K	10	3.573^{e}	1.019	0.322	2.844	4.302	
Elasticity (MOE)	A	10	619.27^{cd}	360.47	113.99	361.40	877.13	
	B	10	1676.15^{ab}	638.09	201.78	1291.69	2132.62	
	C	10	1378.92abc	508.00	160.64	1015.51	1742.32	
	D	10	1846.81^{ab}	899.25	284.36	1203.52	2490.10	
	E	10	2096.14^{a}	882.12	278.95	1465.11	2727.17	*
	F	10	1272.81^{abc}	455.11	143.91	947.24	1598.37	
	G	10	2093.63^{a}	927.40	293.27	1430.20	2757.06	
	H	10	1154.71^{bc}	371.83	117.58	888.71	1420.71	
	K	10	566.86^{cd}	154.53	48.87	456.31	677.41	
Internal bound strength ⊥	A	10	0.076^{d}	0.040	0.012	0.046	0.105	
	B	10	0.265^{bc}	0.037	0.011	0.238	0.291	
	C	10	0.260^{bc}	0.031	0.010	0.237	0.282	
	D	10	0.174^{c}	0.053	0.017	0.135	0.212	
	E	10	0.498^{a}	0.052	0.016	0.460	0.535	*
	F	10	0.179^{c}	0.051	0.016	0.141	0.216	
	G	10	0.421^{a}	0.154	0.049	0.310	0.531	
	H	10	0.064^{d}	0.134	0.004	0.054	0.073	
	K	10	0.309^{b}	0.067	0.021	0.260	0.357	
Tensile strength parallel to surface	A	10	0.901^{g}	0.071	0.022	0.850	0.952	
	B	10	1.783^{ef}	0.089	0.028	1.719	1.847	
	C	10	2.874^{d}	0.330	0.104	2.638	3.110	
	D	10	1.566^{f}	0.162	0.051	1.450	1.682	
	E	10	5.491^{a}	0.355	0.112	5.237	5.745	*
	F	10	2.012^{e}	0.239	0.076	1.840	2.183	
	G	10	3.455^{b}	0.480	0.152	3.111	3.798	
	H	10	2.927^{cd}	0.515	0.163	2.559	3.296	
	K	10	3.320^{bc}	0.216	0.068	3.165	3.475	

Screw holding strength ⊥	A	10	10.627[b]	1.417	0.448	9.613	11.641	*
	B	10	15.027a	1.520	0.481	13.940	16.114	
	C	10	11.690[b]	1.431	0.452	10.666	12.714	
	D	10	11.725[b]	1.371	0.434	10.744	12.706	
	E	10	17.692[a]	2.029	0.642	16.240	19.144	
	F	10	10.545[b]	0.979	0.310	9.845	11.245	
	G	10	16.170[a]	3.775	1.194	13.469	18.871	
	H	10	10.743[b]	1.852	0.586	9.418	12.068	
	K	10	14.780[a]	2.603	0.823	12.918	16.642	
Screw holding strength //	A	10	4.10[c]	1.072	0.339	3.337	4.871	*
	B	10	7.98[bc]	1.090	0.345	7.200	8.760	
	C	10	7.42[bc]	2.932	0.927	5.325	9.521	
	D	10	5.15[c]	1.067	0.337	4.388	5.914	
	E	10	10.33[ab]	2.437	0.771	8.591	12.077	
	F	10	4.67[c]	1.050	0.332	3.924	5.426	
	G	10	9.74[b]	2.527	0.799	7.937	11.553	
	H	10	7.99[bc]	2.085	0.659	6.504	9.488	
	K	10	13.93[a]	4.026	1.273	11.05	16.811	

a,b,c,d, e values having the same letter are not significantly different and vice versa (for Tukey test)

w Standard deviation

x Sampling error

y Minimum value

z Maximum value

* Significance level of 0.05 (for ANOVA).

The PSH values were ranging from 10.545 to 17.692 N.mm^{-2}. These results are equal to the minimum value of perpendicular screw-holding strength (7.2 N.mm^{-2}) required in BS-2684 (2004) standard for general purpose particleboards. And the LSH values performed between 4.10 and 13.93 N.mm^{-2}. All the particleboards have the lateral screw-holding strength comparable to minimum value of the strength (3.6 N.mm^{-2}) required in the BS-2604 (2004) standard.

DISCUSSION

Reinforcement materials supported the experimental panels relatively with MOR between 0.7 and 280 % compared to control group. Sandwiched reinforcement materials had positive effect on MOR properties of board comparison to control group. Particleboard types of E and G (reinforced by PM) had MOR values that were sufficiently high to meet the requirements for general uses particleboards.

Tab. 4: Comparison results with recent studies manufactured by vine pruning.

Test	Standard require	According to		
		Nthalos and Grigorioru	Yeniocak et al.	Our Study
Density (g .cm^{-3})	0.590-0.800	691.00	646.90	0.517-0.738
Thickness swelling 24 h (%)	14	16.00	22.79	12.51-30.84
Moisture content (%)	---	---	---	9.21-10.56
Static bending (MOR) (N.mm^{-2})	11.5	10.90	12.38	3.59-13.60
Elasticity (MOE) (N.mm^{-2})	1600	1518	2841.88	566.86-2096.14
Internal bound strength (N.mm^{-2})	0.24	0.72	0.52	0.06-0.49
Tensile strength parallel to surface (N.mm^{-2})	3.5	---	---	0.901-5.491
Screw holding strength ⊥ (N.mm^{-2})	7.2	10.70	3.24	10.545-17.69
Screw holding strength // (N.mm^{-2})	3.6	8.52	2.02	4.10-13.93

The results indicated that all physical and mechanical properties (density, tickness swelling, static bending, modulus of elasticity, internal bonding strength, tensile strength parallel to surface, screw withdrawal from face and edge) were generally increased with the reinforcement materials. This result contradicting to that by Nthalos and Grigoriou (2002) and Yeniocak (2014).

CONCLUSIONS

In this study, some mechanical and physical performance characteristics of reinforced three-layer, vine pruning particleboards were evaluated while the potential use of vine pruning in the particleboard industry was explored. It was found that vine pruning particleboard made without reinforcement material had weaker mechanical properties. Generally the reinforcement materials were increased the mechanical properties of particleboards. Sandwiched PM (groups E and G) showed perfect performance on all mechanical properties. However, some more materials like CFF, CF, PM and PF can be used as reinforcing materials to vine pruning for the production of particleboards that meet the standards for isolation panels and interior-use.

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Mehmet Yeniocak, Osman Goktas*, Ertan Ozen, Ahmet Gecgel
Mugla Sitki Kocman University
Faculty of Technology
Department of Woodworking Industrial Engineering
Mugla 48000
Turkey
Phone: +902522111700
Corresponding author: ogoktas@mu.edu.tr

Ahmet Gecgel
Orge Yapi Tasarim A.Ş.
Mugla Yolu 3. Km 09000
Aydin,
Turkey