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Full Length Research Paper

The correlation of chemical characteristics and UF-Resin ratios to physical and mechanical properties of particleboard manufactured from vine prunings

Samim Yasar[1]*, Ergun Guntekin[1], Mustafa Cengiz[2] and Hakki Tanriverdi[2]

[1]Department of Forest Products Engineering, Faculty of Forestry, Suleyman Demirel University, Isparta-32260, Turkey.
[2]Department of Chemistry, Faculty of Science and Art, Suleyman Demirel University, Isparta-32260, Turkey.

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In this study, the relationship between chemical characteristics of chips, UF-Resin ratios and physical, mechanical properties of particleboard manufactured from vine prunings was investigated. Before particleboard manufacturing, the chips produced from vine prunings were subjected to chemical pre-treatment such as cold water treatment (CW), 1% NaOH treatment (N) and 1% CH_3COOH treatment (A). FTIR spectra of chips were demonstrated that, the content of OH groups was increased by pre-treatments. Therefore, organic chemical component contents (extractives, holocellulose and lignin) of chips were determined. After producing particleboards, physical and mechanical properties namely; water absorption (WA), thickness swelling (TS), modulus of elasticity (MOE), modulus of rupture (MOR) and internal bond strength (IB) were studied. The multiple linear regression models were developed using physical and mechanical properties of particleboard as dependent variables and extractive, holocellulose, lignin contents and UF-Resin ratio as independent variables. The correlation coefficient (R^2) values of 0.90 and 0.92 for estimating TS and WA confirmed that models produced more accurate results for physical properties than mechanical properties (R^2 values of 0.64, 0.85 and 0.89 for estimating MOE, MOR and IB, respectively).

Key words: Chemical pre-treatments, chemical compounds, particleboard, physical and mechanical properties, vine prunings.

INTRODUCTION

The social, technological and economical developments of people are largely dependent on better utilisation of available resources. From ancient ages, humans have made great use of wood-based products as the most available resource. However, increased environmental consciousness, particularly, on recycling of traditional materials, unprecedented forest resource degradation and global warming has led to world-wide efforts to develop products from non-wood resources.

Environmentally, useful lignocellulosic resources are available in different forms of non-wood based on agricultural residues. Vine prunings which are one of these agricultural residues were investigated as raw material for some wood based products such as particleboard and paper, etc. (Ors et al., 2000; Ntalos and Grigoriou, 2002; Guntekin et al., 2009; Yasar et al., 2009). The vine has been a traditional cultivation in Turkey and it covers 2.7% of all agricultural land. The mentioned value represents 20.9% of total horticultural area. Vine is produced on 567000 ha land, and occupied fourth place in the world for Turkey (Ergenoglu and Tangolar, 2000; Anonymous, 2009). Every year after pruning, large amounts of vine pruning remain as by-products in the field, non-utilized properly.

In the literature, several studies presented that some pre-treatments namely, steam treatment (Colak et al., 2007), resin treatment (Var et al., 2002), acetylation

*Corresponding author: Email: syasar@orman.sdu.edu.tr. Tel: +90 246 2113973. Fax: +90 246 2371810.

Abbreviations: CW, water treatment; **WA,** water absorption; **TS,** thickness swelling; **MOE,** modulus of elasticity; **MOR,** modulus of rupture; **IB,** internal bond strength.

(Chow et al., 1996; Gomez-Bueso et al., 1999; Abdul Khalil et al., 2007), heat treatment (Boonstra et al., 2006), chitosan treatment (Basturk and Guntekin, 2009), sodium hydroxide treatment (Wang and Yu, 1993; Guntekin et al., 2009), water treatment (Guntekin et al., 2009), acetic acid treatment (Guntekin et al., 2009), enzymatic treatment (Zhang et al., 2003) and boric acid treatment (Var et al., 2002; Zaidon et al., 2007) were found to improve properties of particleboard and bio-composites.

This paper presents the results of a study on the assessment of the relationship between chemical properties of chips, UF-resin amount and physical, mechanical properties of particleboard manufactured from vine prunings. Before the particleboard production, the chips were pre-treated with different solvents such as cold water, sodium hydroxide (NaOH) and acetic acid (CH_3COOH). The data for chemical properties of chips were obtained using wood chemistry techniques.

MATERIALS AND METHODS

Materials

This study utilized vine prunings, which were collected from horticultural land of Suleyman Demirel University in Isparta-Turkey.

Methods

Vine prunings were turned into particles through a hammer mill and screened. Particles passed through 3 mm sieves and remained on the 1 mm sieves were used in single layer panel production (Guntekin et al., 2009). After the chipping, the following treatments were applied to the particles; untreated (C), cold water treatment (CW), 1% NaOH treatment (N) and 1% CH_3COOH treatment (A) for 24 h. The pre-treated particles were washed with distilled water before manufacturing (Guntekin et al., 2009).

Then, the particles were dried at 102 ± 5ºC until at least 3% moisture content obtained. In the production of experimental panels; urea formaldehyde (UF) resin was used as binder. As a hardener, 35% of ammonium chloride solution was used. The amount of adhesive utilized in experimental panel production as 6, 8, and 10% dry weight of the particles. After spraying the adhesive on the particles in a drum blender, particleboard mat was manually formed inside a 31 × 35 cm wooden box on a metal caul plate which was used in carrying the mat to the hot press. The target board thickness 12 mm has been achieved in 5 min under 2.5 - 3 N/mm^2 pressure at 150 ± 5ºC. Experimental panels were trimmed to avoid edge effects on test parameters and kept in 20ºC and 65% relative humidity for 48 h. The target board density was 0.5 g/cm^3 (Guntekin et al., 2009).

Modulus of elasticity (MOE), modulus of rupture (MOR), internal bond strength (IB), thickness swelling (TS) and water absorption (WA) properties of the particleboards were evaluated using TSE EN 310 (1999), TSE EN 317 (1999) and TSE EN 319 (1999) standards, respectively. Determination of each physical and mechanical property was carried out in 10 measurements. Some portions of untreated and pre-treated chips were separately milled to pass 40 - 100 mesh in Retsch SK 1 mill and used for following experiments.

The milled chips were primary extracted with 2:1 cyclohexane: ethanol and secondary ethanol using Buchi Extraction System B-811. Extractive contents of milled chips were calculated and expressed in percentage of dry sample weight (w/w). For acid hydrolysis of extracted milled chips, modified method from Dill et al. (1984) was used (Yasar et al., 2009). After hydrolysis, the Klason lignin contents were expressed in percentage of dry sample weight of milled chips (w/w). Holocellulose contents of samples were determined using delignifying (Browning, 1967) of extracted milled chips and also expressed in percentage of dry sample weight of milled chips (w/w).

Determination of extractive, Klason lignin and holocellulose contents was carried out in 5 measurements for each sample. The milled chips were further pulverized with agate mortar and pestle to have particle size from 20 - 45 µm. 10 mg of the each pulverized sample (on oven dry basis) was dispersed in a matrix of 1000 mg KBr, followed by compression of 8 t to form self-supporting pellets. FTIR spectra of the samples were recorded at room temperature using Perkin Elmer BX FTIR Spectrometer. Ten scans per sample were collected.

The FTIR spectrum band at around 3400 cm^{-1} was used defining OH groups (Pandey, 1999, 2005). Baseline for each FTIR spectrum was defined between absorbance value at 4000 and 3010 cm^{-1}. The intensity of OH band was obtained by measuring the peak height defined as absorbance value difference between the band maximum and the baseline. For constituting multiple linear regressions, extractive, holocellulose and lignin contents were used as independent variables. Glue solids (UF-resin) such as 6, 8 and 10% for the particleboards were also applied as independent variables of models. Modulus of elasticity (MOE), modulus of rupture (MOR), internal bond strength (IB), thickness swelling (TS) and water absorption (WA) properties of the particleboards were employed as dependent variables in the structure of models. For statistical evaluations in the study, SPSS for windows software was used.

RESULTS AND DISCUSSION

Physical and mechanical properties of fibreboard and particleboard can be mostly varied by various chemical pre-treatment conditions of fibres and chips (Pan et al., 2007; Lopattananon et al., 2009; Guntekin et al., 2009). MOE, MOR, IB, WA and TS values of particleboards by C, N, CW, A and spraying with different UF-resin ratios are shown in Table 1. The values were determined between 1154 - 1789 MPa, 3.39 - 6.30 MPa, 0.21 - 0.53 MPa, 91 - 132% and 21 - 35% for MOE, MOR, IB, WA and TS, respectively. These results were in agreement with findings from previous study of Guntekin et al. (2009). Mentioned physical and mechanical properties were used as dependent variable in the multiple linear regression models structure.

From the FTIR spectrum, it can be attributed that the strong broad peak of the hydroxyl (-OH) stretching appears around at 3400 cm^{-1} (Pandey, 1999, 2005). The FTIR spectra of C, N, CW and A chips are indicated in Figure 1. OH absorption peak appear in each spectrum, which presents that considerable amounts of OH appear when pre-treated by three different procedures. The intensities of OH peaks were found to be 1.132, 1.173, 1.181 and 1.202 for C, A, CW and N chips, respectively.

The increasing OH group content by chemical pre-treatment has effects on physical and mechanical properties (Pan et al., 2007). Therefore, pre-treated chips were analyzed with regard to the content of organic

Table 1. MOE, MOR, IB, WA and TS values of particleboards manufactured from vine prunings.

Treatment	UF-Resin (%)	MOE (MPa)	MOR (MPa)	IB (MPa)	WA (%)	TS (%)
	6	1154 (260)	3.39 (0.69)	0.21 (0.05)	121 (6)	31 (2)
Untreated [C]	8	1316 (419)	3.75 (1.43)	0.30 (0.09)	110 (15)	25 (7)
	10	1699 (262)	4.17 (0.98)	0.33 (0.09)	91 (12)	21 (6)
	6	1584 (312)	5.16 (0.82)	0.25 (0.06)	132 (6)	35 (5)
NaOH [N]	8	1717 (351)	5.56 (0.84)	0.26 (0.06)	119 (12)	32 (8)
	10	1588 (227)	5.55 (1.00)	0.28 (0.12)	103 (16)	27 (8)
	6	1157 (163)	4.05 (0.48)	0.26 (0.04)	122 (6)	28 (6)
Cold water [CW]	8	1566 (241)	5.67 (0.75)	0.41 (0.08)	110 (2)	29 (4)
	10	1789 (381)	6.29 (0.99)	0.36 (0.13)	103 (11)	24 (11)
	6	1500 (308)	5.04 (1.38)	0.40 (0.12)	109 (18)	32 (6)
CH_3COOH [A]	8	1403 (263)	4.87 (0.97)	0.44 (0.16)	104 (8)	26 (6)
	10	1689 (404)	6.30 (1.58)	0.53 (0.13)	97 (16)	24 (4)

MOE: Modulus of elasticity, MOR: modulus of rupture, IB: internal bond strength, WA: water absorption, TS: thickness swelling and, ( ): standard deviation.

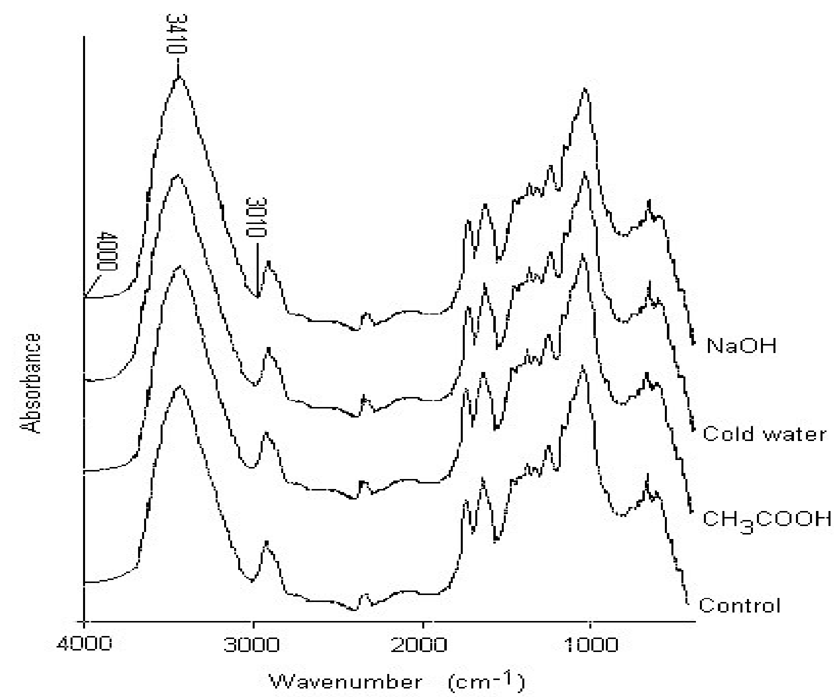

Figure 1. FTIR spectra of vine pruning particles processed with different methods.

components, which occur in the lignocellulosic material and determine most of the properties of lignocellulosic material. Organic substances of lignocellulosic materials are principally composed of polysaccharides (Cellulose and Hemicelluloses), lignin and extractives (Rowell, 1983; Fengel and Wegener, 1984). In Table 2, the contents in vine pruning chips are represented for extractives, lignin and polysaccharides as holocellulose.

By pre-treating with 1% CH_3COOH, cold water and 1% NaOH, respectively, percent ratio of holocellulose content in vine pruning chips was increased, whereas, percent ratio of extractive and lignin contents were decreased (Table 2). UF-Resin ratio is one of the important factors that affects on physical and mechanical properties of

Table 2. Extractive, lignin and holocellulose contens of vine prunings.

Treatment	Extractives (%)	Klason lignin (%)	Holocellulose (%)
Untreated [C]	6.30 (0.041)	23.51 (0.125)	70.38 (0.121)
CH_3COOH [A]	4.59 (0.078)	22.36 (0.233)	73.80 (0.072)
NaOH [N]	4.85 (0.058)	22.62 (0.051)	74.48 (0.088)
Cold Water [CW]	4.76 (0.088)	22.54 (0.069)	74.19 (0.077)

( ): Standard deviation.

Table 3. Accuracy of constructed multiple linear regression models.

Model	R^2
5161.22E + 539.72H – 6192L + 85.63UF + 75778 = MOE	0.64
3.46E + 0.57H – 4.87L + 0.29UF + 54 = MOR	0.85
-0.7E – 0.17H + 0.4L + 0.024UF + 6.95 = IB	0.89
61.96E + 14.87H – 44.44L – 5.63UF – 239.75 = WA	0.92
167.83E + 17.63H – 198.57L – 1.88UF + 2410.53 = TS	0.90

E: Extractive content, H: holocellulose content, L: lignin content, UF: UF-resin ratio, MOE: modulus of elasticity, MOR: modulus of rupture, IB: internal bond strength, WA: water absorption and TS: thickness swelling.

Particle board (Haygreen and Bowyer, 1989). Therefore, we used UF-Resin ratio as independent variable in the multiple linear regression models besides chemical components (extractives, holocellulose and lignin).

The multiple linear regression models were developed for estimating the physical and mechanical properties of particleboard manufactured from vine pruning using extractive, holocellulose, lignin contents and UF-Resin ratio. Where, E is extractive content, H holocellulose content, L lignin content and UF-Resin ratio as independent variable, MOE, MOR, IB, WA and TS are as dependent variable (Table 3). When multiple linear regression models were allowed to predict the physical properties such as TS and WA, the results were found generally high with correlation coefficient (R^2) values of 0.90 and 0.92, respectively. For estimating mechanical properties namely, MOE, MOR and IB, multiple linear regression models were performed with lower R^2 values of 0.64, 0.85 and 0.89, respectively.

Conclusion

The multiple linear regression models were developed for determining relationship between chemical characteristics of chips, UF-Resin ratios and physical, mechanical properties of particleboard manufactured from vine pruning. Extractive, holocellulose, lignin contents and UF-Resin ratios as independent variable and MOE, MOR, IB, WA and TS as dependent variable were used in the model structures. It was shown that the models performed better for physical properties than mechanical properties. The correlation coefficient (R^2) values of models were found to be 0.64, 0.85, 0.89, 0.90 and 0.92 for MOE, MOR, IB, TS and WA, respectively.

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