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Chemical composition of tomato (*Solanum lycopersicum*) stalk and suitability in the particleboard production

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Abstract: *This study examined chemical composition of tomato stalks and their possible feasibility in the production of particleboard. Three-layer experimental particleboards with density of 0.53, 0.63, and 0.73 g cm^{-3} were manufactured from tomato stalks using certain ratios of urea formaldehyde (UF) and melamine urea formaldehyde (MUF) adhesives. Modulus of elasticity (MOE), modulus of rupture (MOR), internal bond strength (IB), thickness swelling (TS) properties of the boards were evaluated, and a statistical analysis was performed in order to examine possible feasibility of these stalks in commercial particleboard manufacturing. The experimental results have shown that production of general purpose particleboard used in dry conditions using tomato stalks is technically viable. The results of the study demonstrate that tomato stalks can be an alternative raw material source for particleboard industry. Use of agricultural waste such as tomato stalk can help solving waste management problems and contribute conservation of natural resources.*

Key words: *Tomato stalks, Chemical composition, Particleboard, Properties*
PDF of full length paper is available online

Introduction

Wood composite industries demand more wood raw material everyday despite the fact that the forest resources are diminishing. The decline in wood material source has led researchers to study non-wood ligno-cellulosic biomass utilization in composite manufacturing including particleboard. Agricultural waste materials and annual plant fiber have become alternative raw materials for the production of particle or fiber composite materials. The most frequently referred alternative non-wood materials are flax, bagasse, hemp, reed, and cereal straws such as rice and wheat straw (Younquist *et al*., 1994). Today chemical pulp and panel products using wheat straw and other crop residues are being commercially manufactured in a number of countries including Turkey (Copur *et al*., 2007). There is still a growing need to find alternative sources of raw materials for composite manufacturing.

Recently, several studies have investigated the suitability of new substitutes, including cotton stalks (Guler and Ozen, 2004), cotton carpel (Alma *et al*., 2005), hazelnut husk (Copur *et al*., 2007), vine prunings (Ntalos and Grigouriou, 2002), bamboo chips (Papadopoulos *et al*., 2004), kenaf core (Xu *et al*., 2004; Grigouriou *et al*., 2000a), kenaf core and bast fiber chips (Grigoriou *et al*., 2000b), date palm branches (Nemli *et al*., 2001), wheat straw (Zhang *et al*., 2003), peanut-shell flour (Batalla *et al*., 2005), sunflower stalks (Bektas *et al*., 2005) and eggplant stalks (Guntekin and Karakus, 2008) in order to utilize in particleboard manufacturing and they have been found technically suitable. Agricultural residues are also utilized for different purposes such as waste water treatment (Ahalya *et al*., 2007) and commercial enzymes production (Huitron *et al*., 2008). Use of agricultural residues can contribute both in solving waste management problems and raw material shortage for wood composite industries.

The high cost of collection, transporting, and storing of agricultural residues are still the main obstacles for using these materials in the forest products industry. Some of these problems could be overcome by building local, small scale mills close to the rural areas (Copur *et al*., 2007). According to Ndazi *et al*. (2006), agro-based composites may in the future, become materials to replace polymer based composites and wood in terms of their attractive specific properties, lower cost, simple process technologies, eco-friendliness, and ability to be recycled after using. The quality and performance of plant-based composites can be improved by adopting appropriate processing techniques.

Tomato (*Solanum lycopersicum*) is an annual plant which grows 1-3 m tall in the Solanaceae family, native to central, south, and southern north America from Mexico to Peru. In 2005, China was the largest producer of tomatoes. China accounted for at least one-fourth of the global output followed by USA and Turkey. More than 4 million ha land is devoted to the cultivation of tomato in the world. Approximately 1 million ha land is utilized for vegetable farming including tomato, eggplant and pepper in Turkey (Seniz, 2004). A small town in Antalya region generates more than 100 000 tons of dry agricultural waste every year. Until recently, vegetable stalks including tomato residues have been thrown away or burned, but disposal costs are rising and burning creates environmental problems. Recent economic, technological and political changes are opening up new markets for agricultural wastes. These markets could provide the foundation for a re-industrialization of many rural economies.

The objectives of this study are to investigate chemical properties of tomato stalks and examine some physical and mechanical properties

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(modulus of rupture (MOR), modulus of elasticity (MOE), internal bond strength (IB) and (thickness swelling (TS) of the experimental boards. Information is required before the commercialization of these agricultural residues to value-added products.

Materials and Methods

The tomato stalks used in the study was collected in green form in Antalya region of Turkey. The stalks were transported to Forest Products Engineering facilities in Isparta and stored in sheltered environment for six months before utilizing in the production. They were cleaned from roots, then turned into particles through a hammer mill and screened.

To investigate chemical composition; specimens were prepared with Wiley mill and ground to pass various mesh screens. In order to determine extractive content, samples were extracted with ethanol:benzene (1:2 v/v) solution according to TAPPI test method T-204 (TAPPI, 1992). Holocellulose was isolated from extractive-free samples. Approximately, 100 mg of ground tomato residue was suspended in 2 ml of deionised water in a round bottom flask. The reaction flask then submerged in a hot water bed maintained at 90°C. In order to start reaction, 0.5 ml of sodium chlorite solution was added. At 30 min intervals 0.5 ml sodium chlorite/acetic acid solution was added to reaction flask for a total of 2 ml. At the end of 2 hr, reaction was stoppped, cooled, and filtered using a sintered glass filter (medium). The resulting holocellulose was washed with 50 ml (4 times) deionised water and dried in an oven at 105°C and the yield of holocellulose was determined.

In order to determine α-cellulose content, 50 mg portion of the oven dried holocelluloce was weighed in to a 10 ml beaker and left to stand at room temperature for 30 min to allow moisture equilibration. Into this sample, 4 ml of 17.5% NaOH was added and left reacting for 30 min. Deionised water (4 ml) was added to this mixture and waited for another 30 min. After total of 1hr reaction period, the fiber suspension was filtered with sintered glass filter (medium) washed thoroughly with deionised water and soaked in 1M acetic acid solution for 5 min. neutralized α-cellulose content washed with deionised water and the yield was determined after the sample was oven dried at 105°C.

For experimental particleboard production; particles remained on the 2.0, 2.5 - 3.0 and 1.0-1.5 mm sieves were used in middle-layer and surface-layer on panel production, respectively. Then the particles were dried at 103±5°C until at least 3% moisture content obtained. In the production of experimental panels; urea formaldehyde (UF) and melamine urea formaldehyde (MUF) resins were used as binder. Properties of the adhesives are given in Table 1. As a hardener, 35% of ammonium chloride solution was used for all of the UF resin panels. Table 2 presents experimental design set up for the study of 12 board type samples. After spraying the adhesive on the particles in a drum blender, particleboard mat was manually formed inside a 40 x 40 cm wooden box on a metal caul plate which was used in carrying the mat to the hot press. The shelling ratio; the ratio of the outer thickness to the total thickness of the boards was 0.35 for all experimental boards. The target board thickness (16 mm) has been achieved in four minutes under 2.5-3 N mm^{-2} pressure at 155±5°C. Two experimental boards have been manufactured representing each treatment group. Experimental panels were trimmed to avoid edge effects on test parameters and kept in 20°C and 65% relative humidity for 48 hr. Test samples were cut from the experimental panels to determine some physical and mechanical properties in accordance with TS EN 310 (1999), TS EN 317 (1999) and TS EN 319 (1999) standards. Collected data were statistically analyzed using analysis of variance (ANOVA) and Duncan's mean separation tests.

Results and Discussion

Chemical composition of tomato stalks are listed in Table 3 which indicates that tomato stalks had very low lignin content when compared to some other agricultural residues and wood. Extractive and holocellulose contents seem to be very high when compared to other ligno-cellulosic materials.

Average values of MOE, MOR, IB and TS values obtained from the test samples are presented in Table 4. A two-way analysis of variance (ANOVA) general linear model procedure was employed for data to interpret principal and interaction effects on the properties of the panels manufactured. Duncan test was used to make comparison among board types for each property tested if the ANOVA found significant.

Table - 1: The properties of the adhesives used

Properties	UF	MUF
Solid content (%)	65 ± 1	55 ± 1
Density (g cm^{-3})	1.27-1.29	1.125
pH (25°C)	7.5-8.5	8.5
Viscosity (cps, 25°C)	150-200	200
Gel time (s, 100°C)	25-30	50-60
Storage time (day, @ 25°C)	60	60
Flowing time (s, 25°C)	20-30	20-40
Free formaldehyde (max) %	0.19	0.16

Table - 2: Experimental design used in the study.

Board type	Density g cm^{-3}	Adhesive Type	Adhesive used (%)	
			Middle	Surface
A	0.53	UF	8	10
B	0.63	UF	8	10
C	0.73	UF	8	10
D	0.78	UF	8	10
E	0.53	UF	10	12
F	0.63	UF	10	12
G	0.73	UF	10	12
H	0.78	UF	10	12
I	0.53	MUF	10	12
J	0.63	MUF	10	12
K	0.73	MUF	10	12
L	0.78	MUF	10	12

Table - 3: Chemical composition of tomato stalks and its comparison with some other agri-residues and wood

	Extractive content (%)	Lignin content (%)	Holocellulose content (%)	α-Cellulose content (%)
Tomato	7.14	4.15	88	40,53
Cotton carpel (Alma *et al.*, 2005)	5.54	20.5	71	42.5
Cereal straw (Eroglu, 1988)	3-12	12-17	64-71	35-39
Hazelnut husk (Copur *et al.*, 2007)	8.22	35.1	55	34.5
Softwood (Fengel and Wegener, 1989)	0.35	25-35	63-70	29-47
Hardwood (Fengel and Wegener, 1989)	0.35	30-35	70-78	38-50

Table - 4: Some properties of the boards manufactured using tomato stalks

Board	MOR ($N\ mm^{-2}$)	MOE ($N\ mm^{-2}$)	IB ($N\ mm^{-2}$)	TS (%)
A	5.4^{E} (1.2)	1328^{D} (237)	0.3 (0.08)	70^{C} (12.4)
B	7.4^{DC} (2.4)	1907^{CB} (573)	0.43 (0.27)	103^{BA} (7)
C	8.04^{DC} (1.4)	1994^{CD} (424)	0.48 (0.4)	113^{A} (9)
D	9.87^{BC} (0.9)	2034^{C} (466)	0.51 (0.6)	121^{A} (15)
E	6.65^{DE} (1.2)	1758^{CD} (418)	0.4 (0.3)	67^{C} (16)
F	8.6^{DC} (1.5)	2385^{B} (174)	0.65 (0.1)	93^{B} (13)
G	10.89^{BA} (0.4)	3041^{A} (100)	0.53 (0.06)	90^{B} (8)
H	12.13^{A} (0.34)	3098^{A} (122)	0.56 (0.05)	95^{B} (12)
I	7.72^{DC} (2.9)	2295^{CB} (730)	0.73 (0.75)	50^{D} (11)
J	9.23^{BC} (2)	2296^{CB} (760)	0.44 (0.18)	67^{C} (17)
K	12.17^{A} (1.9)	2481^{B} (656)	0.69 (0.33)	73^{C} (12)
L	12.75^{A} (2.2)	2667^{B} (544)	0.71 (0.41	75^{C} (14)

* = Each value represents the mean of 6 replications. Values sharing the same capital letter within a column are not statistically different at the 0.05 level of confidence. Values in parentheses are standard deviations

The MOR and MOE mean values presented in Table 4 ranged from 5.4 to 12.75 N mm^{-2} and from 1328 to 3041 N mm^{-2} respectively. The MOR and MOE of the experimental particleboards increased with an increase in panel density and adhesive ratio. This suggests that the board density and adhesive ratio had significant effect on the MOR and MOE as wood-based particleboard. Therefore it may be possible to manufacture stronger and stiffer boards by increasing production variables involved in this study. The bending properties of the boards were strongly dependent on the density than the adhesive ratio. The IB mean values ranged from 0.3 to 0.73 N mm^{-2}. While similar tendency was expected between IB strength and density, it is interesting to find out that neither the amount of adhesive nor the level of density has significant effect on IB of the boards.

L-type boards achieved the highest MOR values while A-type boards gave the lowest MOR values as expected. Considering only MOE values; most of the board types comply with the minimum requirements for general grade particleboards. Test results indicated that H, K and L type boards conform to the minimum requirements for general grade particleboards as indicated by TS EN 312 (1999).

The results indicated that particleboards produced using tomato stalks gave extremely high amount of TS values compared to the boards made from wood and other ligno-cellulosic materials such as cotton stalks (18-35%), date palm branches (7-18%), kenaf core (18-41%), cotton carpels (16-31%), hazelnut husk (16-29). This could be explained by strong polar character of plant fibers which creates problems of incompatibility with adhesive matrices (Ndazi *et al.*, 2006). Adding water repellent chemicals such as paraffin during the board production may reduce the rate of thickness swelling and water absorption (Copur *et al.*, 2007). Use of phenolic resins may also decrease the rate of thickness swelling because they will not dissolved when get in contact with water.

Utilization of smaller particles in the surface layers may yield to panels that have better physical and mechanical properties. Furthermore, these stalks could also be mixed with wood chips to achieve better panel properties.

The results indicated that the manufacture of particleboards from tomato stalks using UF and MUF adhesives is technically viable. The MOR and MOE increased as the panel density and adhesive ratio increased; whereas IB was consistent for all panel types.

Use of renewable materials such as tomato stalks for manufacturing particleboards could contribute the solution of raw material shortage for the particleboard industry and some environmental problems due to the burning can be prevented. The pressure on other forest resources can be reduced and some job opportunities can be created. Use of tomato stalks in the manufacture of particleboard could benefit the farmers and alleviate poverty. Furthermore, use of agricultural residues can contribute both in solving waste management problems and raw material shortage for wood composite industries.

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