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EFFECTS OF CHITOSAN TREATMENT ON SOME PARTICLEBOARD PROPERTIES

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ABSTRACT

The purpose of this study was to improve some physical properties of particleboard using chitosan treatment. Particleboard is a main product for furniture industry and also used as a home decoration material in Turkey; however, it has a poor dimensional stability. In this study, wood particles, which were obtained from a commercial plant, were treated with chitosan acetate solutions (2% wt). Treated particles before the assembly also had extra high-heat treatment to convert insoluble chitosan acetate film over the particles to insoluble chitin. Different time intervals and temperature regimes were used in this experiment to select suitable temperature and time for chitosan acetate conversion to chitin. 6% liquid phenol-formaldehyde resin was used based upon oven-dry weight. The mat was pressed at 200°C for 8 minutes to form 1.2 cm thick and a target of 0.66 g.cm^{-3} density panel. Physical properties of the chitosan treated particleboards were improved; thickness swelling and water gain of the chitosan treated panels were reduced over untreated control panels after the 24-hour water-soak test. There was positive significant effect of chitosan treatments on internal bond strength.

KEY WORDS: particleboard, dimensional stability, chitosan.

INTRODUCTION

Wood is a hygroscopic material, which swells as it absorbs/adsorb moisture and shrinks as it looses moisture below the fiber saturation point. Dimensional changes are different with reconstituted wood products, such as fiberboard and particleboard, from solid wood products. For example, thickness swelling of flakeboard when exposed to moisture is greater than would be expected from the normal shrinking and swelling of the component wood strands (Rowell et al. 1986). In addition to that swelling, water contact or high relative humidity can greatly affect the state of stress that exits in the material. The in-plane movements can cause high internal stresses due to the restraint by metal fasteners. These stresses may be large enough to cause buckled panels, pushed out nails, and separation of the panel from the structure.

Dimensional stability of wood based panels can be affected by most process variables such as wood-furnish, flake size and geometry, resin level and type and pressing conditions (Kelly 1977). Improved dimensional stability should be possible through a better understanding of these variables as well as by special treatments such as chemical modifications, steam and heat treatments and special coatings. The use of special treatments to improve the dimensional stability of panel products has followed the lead of solid wood research.

Dimensional stability of particleboard can be improved permanently with chemical modifications (such as, with acetylation to alter the wood matrix by replacing the polar hydroxyl groups with bulkier, less hydrophilic acetate groups). Rowell et al. (1986) studied acetylation of flakes and reported substantial reductions in thickness swelling and water gain, but it takes some times.

Resin impregnation, heat and steam treatments have been used for dimensional stability of the particleboard and waferboard. These treatments were effective; unfortunately they were costly or reduced the mechanical properties of the panels (Haygreen and Gertjejansen 1972, Geibeler 1983). Improving the dimensional stability of woodbased panels should not be a goal in itself to the extent that the other properties of the panels, such as strength and stiffness, are adversely affected or the product becomes prohibitively expensive.

Chitosan is a modified carbohydrate polymer derived from chitin, one of the most abundant polysaccharides in nature, by deacetylation. Chitin occurs as a component of crustacean shells, insect exoskeletons, fungal cell walls, microfauna and plankton. Chitosan is a polysaccharide formed primarily of repeating units of beta (1-4) 2-amino-2-deoxy-D-glucose (or D-glucosamine). Generally, about 70-90% of the units are deacetylated, with the remaining 10-20% acetylated (Sandford 1988). Today, chitosan is used widely in medical, health, waste management and agricultural areas.

Although chitosan films, even when not dissolved, are more or less swollen by water, the amount of swelling is reduced by heating, formaldehyde treatment or acetylation which produces chitin again. In this research, heat is applied to make chitosan chitin again. Chitosan is used as a paper sizing or additive to improve paper mechanical properties and water resistance. Moreover, it has been used for improving water resistance of the textile, wool, and bonding properties for tobacco and solid wood (Muzzarelli 1977).

The main objective of this study was to improve dimensional stability of particleboards by chitosan treatment. Different temperature and time intervals were applied to find out if there is any difference between time and temperature regimes for converting water-soluble chitosan acetate to water-insoluble chitin. Internal bond properties of the experimental panels were also evaluated.

MATERIAL AND METHODS

The wood particles used in this study were obtained from a commercial particleboard plant. Wood particles were consisting of hardwood species. Due to the difficulty of treatments and handling of small particles, only coarse particles are utilized in this experiment and homogenous one-layer panels produced at the laboratory conditions.

Industrial chitosan was obtained from Natural Biopolymer, Inc, Raymond, WA. (USA) Chitosan obtained as a flake form and used as a liquid chitosan acetate solution. Forty five grams of chitosan flake was added to 2 L of 3% aqueous acetic acid solution (60 ml glacial acetic acid added to 2000 ml distilled water) to obtain 2% (wt) chitosan acetate solutions. These aqueous mixtures, pH 4, were stirred vigorously at a temperature of ~60°C for two hours. Dissolved chitosan solutions

(chitosan acetate) were cooled to 21°C, and stored in closed glass bottles until particle treatment; the solutions were used in a week so refrigeration was not necessary.

Two different temperatures and times settings were applied to wood particles as treatments and total of four groups were established as following. Group A; particles immersed in 2% chitosan acetate solution and blended to take all solution by wood particles, to established 2% chitin layer based on oven-dry wood weight. Particles let to air dry for 24 hours, after particles put an oven for 90 minutes at 100°C and heat raised to 120°C for 15 minutes. Later, particles were sealed in plastic bags to prevent moisture intake prior to board pressing.

Group B; particles immersed in 2% chitosan acetate solution and blended to take all solution by wood particles, to established 2% chitin layer based on ovendry wood weight. Particles let to air dry for 24 hours, after particles were placed in oven for 90 minutes at 100°C and heat raised to 140°C for 15 minutes. Later particles were sealed in plastic bags to prevent moisture intake prior to pressing.

Group C; particles immersed in 2% chitosan acetate solution and blended to take all solution by wood particles, to established 2% chitin layer based on ovendry wood weight. Particles let to air dry for 24 hours, after particles were placed in oven for 180 minutes at 100°C and heat raised to 140°C for 15 minutes. Later particles were sealed in plastic bags to prevent moisture intake prior to pressing.

Group D particles were not treated with chitosan acetate. This group was used as a control group. Other parameters were the same with treated panels.

Treated and untreated (control panels) particles put in an oven (102 ±5°C) to get particles to 3% MC before resin application. No wax emulsion was used during this experiment. Liquid phenol formaldehyde resins were obtained from Borden Chemical Company, Cascophen 0303D for board and 6% resins were sprayed onto particles. Furnish-mat established by hand and size was 25x25 cm. Then, they pressed at 200°C for 8 minutes within 30 seconds closing time and 2 minutes breathing time. Target density was 0.66 g. cm^{-3} with 1.2 cm mat thickness.

Before the water soak test, some adjustments have been made due to small press size. Test samples were cut 5 by 5 cm and conditioned at 21°C and 50% RH. The thickness was measured to the nearest 0.001 mm with a micrometer at four point midway along each side of the specimens. Then they were submerged horizontally under 3 cm of distilled water, maintained at a temperature of 20±1 °C. The measurements of weight and thickness were taken during 24 hours.

Internal bond test, specimens 5 x 5 cm sizes were used for the determination of the internal bond and conditioned at 65% RH and 20°C in an Aminco-Aire relative humidity chamber for one week prior to test. Each sample was bonded to a pair of 5 x 5 cm aluminum blocks with hot melt glue. A Riehle Universal Testing Machine was used to apply the load at a uniform-crosshead motion-rate of 0.1 cm per minute. Tests and data analyses were performed according to ASTM D 1037-96a.

RESULTS AND DISCUSSION

Average values of thickness swelling (TS), water gain (WG), and internal bond (IB) values obtained from the test samples are presented in Tab.1 and 2. Analysis of variance (ANOVA) general linear model procedure was employed for data with SAS statistical analysis software 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.

Tab. 1: Mean values of TS and WG for panels manufacture

Group	Time (Hour)	N	TS (%)	WG (%)
A	1	13	5.65 (1.13)	26.40 (3.6)
	2	13	9.32 (2.10)	35.00 (3.88)
	6	13	15.03 (1.55)	49.11 (3.91)
	12	13	17.11 (1.48)	55.82 (4.77)
	24	13	18.27 (1.43)	63.49 (3.99)
B	1	13	5.19 (1.41)	24.90 (3.39)
	2	13	8.51 (1.32)	34.18 (3.63)
	6	13	13.95 (1.64)	47.43 (3.82)
	12	13	15.82 (2.70)	54.40 (3.61)
	24	13	17.52 (2.33)	60.75 (3.24)
C	1	13	4.05 (1.15)	14.34 (1.79)
	2	13	5.79 (1.52)	19.97 (2.62)
	6	13	11.55 (2.05)	31.35 (3.44)
	12	13	15.88 (2.43)	39.61 (3.44)
	24	13	18.56 (1.64)	47.53 (3.04)
D	1	13	24.69 (1.04)	54.96 (2.37)
	2	13	26.60 (1.17)	58.02 (3.04)
	6	13	28.48 (1.39)	63.49 (2.70)
	12	13	29.06 (1.57)	66.93 (2.31)
	24	13	30.28 (1.67)	70.27 (2.92)

* Values in parentheses are standard deviations.

Tab. 2 : Mean values of IB (MPa) for panels manufactured

Group	N	Mean	Std Dev	Minimum	Maximum	cov
A	10	1.13 B	0.16	0.91	1.40	14.15
B	10	1.10 B	0.11	0.91	1.21	10.00
C	10	1.47 A	0.21	1.11	1.74	14.28
D	10	0.74 C	0.18	0.35	1.03	24.32

* Values sharing the same capital letter within a column are not statistically different at the 0.05 level of confidence.

ANOVA tests indicate that chitosan treatment had significant effects on TS, WG, and IB properties of laboratory made particleboards ($p < 0.001$). TS and WG are the most important properties for the dimensional stability of wood-based products. All chitosan treatments significantly reduced the TS of the treated panels during 24 hours water soak test (Fig. 1). After two hours, TS of chitosan treated panels were reduced an average of 70% for all treatments, group C was the best and group B, A followed respectively. After 24 hours soak, group B and A were the best with average of 47% reductions and group C was 37% over untreated control panels.

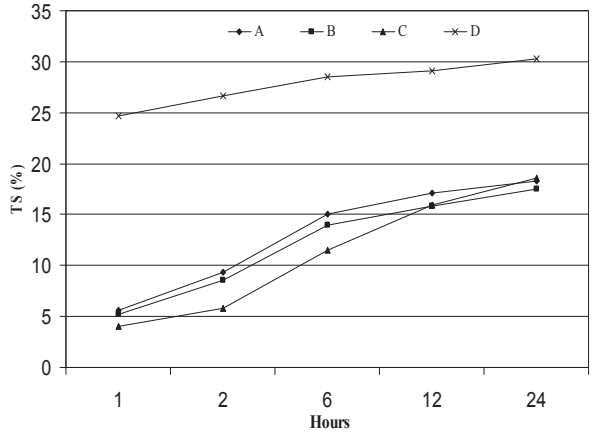

Fig.1: TS (%) of the panels during 24-hour water soak test

The reduced TS of the particleboard panels may be attributed to a chitin film encapsulating the wood particles and blocking some of the cellulose hydrophilic hydroxyl groups at the chitin/cellulose interface. Water-soluble chitosan acetate was converted to water-insoluble chitin by high-heat during heat treatment. This converted chitin acted as a water barrier layer around the particles and this reduced the thickness swelling of the all chitosan-treated panels. Similar results were observed with anti-shrinking effect of chitosan for wool (Masri et al. 1986).

Chitosan treatment also reduced the WG of the treated panels by its barrier effect. After two hours water soak, WG of chitosan treated panels was reduced average of 40% for group A and B, respectively, after 24-hour soak and remained the same which were reduced average of 14%, respectively, over untreated control panels. Group C gave the best results 67 and 33% reduction after the 2 and 24 hours water soak test measurements (Fig. 2).

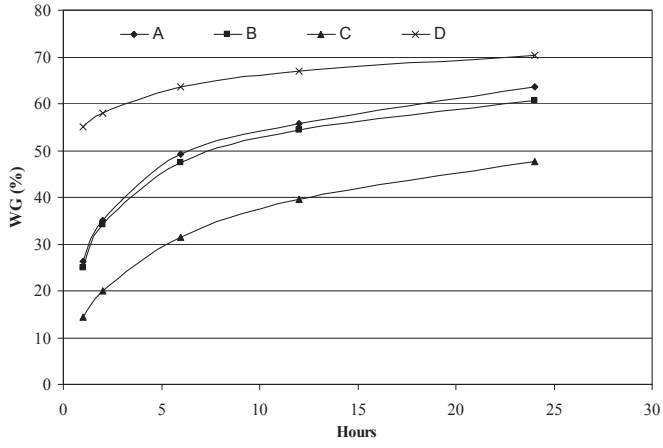

Fig. 2: WG (%) of the panels during 24-hour water soak test

There is a strong correlation between TS and WG reductions of chitosan treated panels. After the 2-hour and 24-hour of water soak TS and WG reductions are almost identical to each other and this supports the barrier theory. After 24-hour water soak, WG were low; on the other hand, TS after 24-hours was still around 30% and this is also shows chitin cover works for dimensional stabilization. Chitin that behaves like thermoset material (Toffey et al. 1996) mechanically restrains panel thickness swelling, and therefore reduces the reversible and irreversible thickness swelling of the chitosan treated panels.

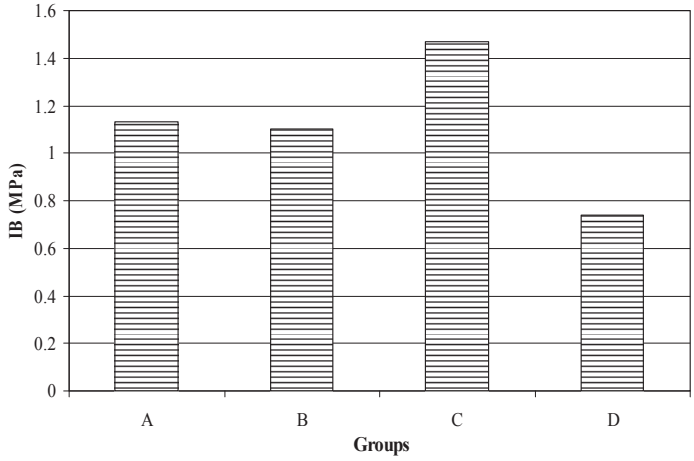

Fig. 3: IB of the panels manufactured

Chitosan treatments had also significant effects on IB of the panels. The IB test results are shown in Fig. 3 compares with the untreated control samples. Duncan test (Tab. 3) indicates that group C had the highest IB strength while group A and B were not significantly different. The untreated group D had the lowest IB strength. Chitosan treatments seem to increase the IB of the panels.

CONCLUSION

Dimensional stability of laboratory-made particleboard panels was improved by chitosan treatments. Flake form chitosan used as a water-soluble chitosan acetate solution and that applied onto the wood particles, later that converted into water-insoluble chitin during heat treatment. Three treatment groups were close enough to each other's, all of them were successfully worked in case of thickness swelling and water gain. Nonetheless, the treatment at 120°C, group A, can be recommended for the heat applied chitosan treatments in the production of particleboards, because of low temperature and less time consuming. This chitin film acts as a water barrier layer around the particles, which reduced significantly the thickness swelling and water gain of the treated panels. Effect of chitosan treatments on IB strength was also significant. To evaluate the effect of chitosan treatments on modulus of elasticity and modulus of rupture, bending tests may be conducted.

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