SELECTED CHEMICAL MODIFICATIONS OF RED OAK AND HARD MAPLE FLAKES FOR FLAKEBOARD MANUFACTURING

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ABSTRACT

The feasibility of using low chemical concentrations, time, and pressure for modifying red oak and hard maple flakes was investigated. Red oak and hard maple flakes were pretreated with water, sodium hydroxide, and acetic acid for different times and pressures to determine weight loss. The chemically modified flakes were processed into flakeboards. Untreated aspen, red oak, and hard maple panels were used as controls. Compared to the hard maple controls, hard maple panels had a reduction in press closing time for all treatment levels. However, a reduction in press closing time for treated red oak compared to red oak controls was evident only for very high weight loss values. Weight loss for red oak and hard maple can be controlled, and it appeared that acetic acid treatments produced better properties for both species compared to sodium hydroxide or water treatments. Mechanical properties were reduced in hard maple for all treatments and in red oak for some treatments, particularly sodium hydroxide treatments. Bending strength values for acetic acid-treated red oak panels were not significantly different from red oak control values. Water and acetic acid treatments for red oak produced similar dimensional stability values compared to red oak controls. This indicated that weight loss can be controlled without detriment to the dimensional stability of the panels. Density, internal bond, thickness swell, water absorption, and linear expansion values for red oak control and acetic acid-treated red oak panels compared favorably with aspen control panels. Density, internal bond, thickness swell, water absorption, and linear expansion values for hard maple control and linear expansion values for water and acetic acid-treated hard maple panels also compared favorably with aspen control panels.

Keywords: Flakeboard, red oak, hard maple, chemical pretreatments.

INTRODUCTION

Studies on the use of hardwoods and softwoods in wood composites such as particleboard, oriented strand board, and waferboard show that wood density is the most important species factor influencing panel properties (Larmore 1959; Johnson 1956; Maloney 1977; Moslemi 1974; Hunt et al. 1978). For production purposes, low density species are favored and desirable because these species produce a panel that exhibits better mechanical properties compared to boards

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produced from high density species (Moslemi 1974; Hse 1975). A ratio of 1.3: 1.0 (board specific gravity to species specific gravity) has been used as a guideline to determine which species may be used to make suitable medium density structural board products.

Investigations on utilizing hardwoods, particularly the dense hardwoods for flakeboard manufacture, have been reported. Hse (1975) found that MOR values differed significantly with wood species, and reported that the three species with the highest density examined (hickory and southern red and white oak) produced panels with significantly lower internal bonds compared to the other lower density species examined. Studies by Price (1976) and Price and Hse (1983) using seven species of southern bottomland hardwoods in various combinations indicated that production of a panel with acceptable properties was technically feasible using several fabrication arrangements such as a 55:45 percent blend (by weight) of low density to high density species. Kelly and Price (1985) recently reported that structural flakeboard panels composed of a mixture of hardwoods exposed to weatherometer tests did not perform as well as commercial waferboard. These results indicated that a mixture of hardwoods, compared to waferboard constructed with a single species, may have some dimensional stability problems.

Variations in the same species grown in different locations have been reported to influence the curing rate of a resin (Maloney 1977). Beer (1982) found flake geometry to differ greatly according to species density and flaker operating characteristics. Springate (1980) evaluated the use of aspen, white birch, and red maple and concluded that high quality panels can be produced from these species mixtures. He reported that no more than 10% of the species mixture used in the blend can be birch without having an adverse effect on panel density.

Another approach in the utilization of dense hardwoods, other than as a small percentage of a species mixture in flakeboard, is to pretreat and modify the flakes with steam or chemicals in order to alter flake properties. Removal of wood constituents by chemical modification of wood or wood flakes will change the properties of wood compared to untreated material. Chemical pretreatments of flakes to improve bonding of flakes in flakeboard have been reported by Zavarin (1984), Chapman and Jenkin (1986), and Roffael and Rauch (1974).

Additional research on changes in the properties of wood after heating for different periods of time has been reported. Davis and Thompson (1964) evaluated toughness and chemical changes taking place to oven- and steam-heated (20 to 120 min) longleaf pine, southern red oak and Douglas-fir specimens. They found a significant reduction in toughness and carbohydrate content in all species, with red oak being more sensitive than the pine and fir, particularly for the specimens heated in steam. Toughness is usually not considered an important engineering design parameter in structures. Reductions in strength and weight were reported by MacLean (1951, 1953) and discussed by Koch (1972) for heating periods of up to and beyond 32 hours for different heating mediums and temperatures. Strength reductions in modulus of rupture (greater than 10%) and weight losses, to some extent, were large for periods of heating time beyond about 3 hours.

Recently Rowell et al. (1986) reported on the properties of flakeboard made from aspen and southern pine wood flakes reacted with gaseous ketene. They reported that both species, chemically modified by reaction with ketene, had greatly reduced the rate and extent of water swelling compared to control boards.

Ketene modification had a much greater effect on improving dimensional stability properties of aspen flakeboards compared to southern pine flakeboards.

In another study, Jahan-Latibari (1982) examined the effects of various surface treatments, including heat and/or chemicals, on the mechanical strength properties of aspen flakes to improve flakeboard properties. The surface treatments used were 3% nitric acid with and without 6% sucrose, and 4% ammonium nitrate with and without 6% sucrose. This study by Jahan-Latibari (1982) was designed to evaluate the chemically modified surface of the flakes to determine whether these treatments enhanced bonding and board dimensional stability. He found no change in flake MOR or MOE shortly after application of chemicals. However, lower flake MOR was found with all surface modifications after heat treatment, although all flake MOE values increased by surface modifications. After exposure to elevated temperatures in the hot press, the MOE and MOR values for the flakes were reduced irrespective of which surface modification system was used. Jahan-Latibari (1982) attributed the loss in both MOE and MOR after hot pressing to embrittlement of the flakes when compared to untreated control flakes.

This study was designed to examine the feasibility of modifying high density hardwood flakes by mild chemical modification as a means of altering the chemical and physical properties of flakes in order to produce high quality, medium density flakeboard. Specific objectives were to: 1) determine the effects of mild alkali/organic acid chemical modification pretreatments on average flake weight loss for red oak and hard maple; and 2) evaluate the effect of flake pretreatment and modification on single hardwood species flakeboard strength properties and dimensional stability.

PROCEDURES

The purpose of this project was to evaluate the feasibility of chemically modifying the flakes prior to manufacturing flakeboard. This feasibility was determined using good quality flakes (about 3 in. long × ⅜ in. wide × 0.020 in. thick) and comparing the flakeboard properties of untreated aspen, red oak, and hard maple with the treated red oak and hard maple hardwood panels. The flakes were maintained in an oven-dry condition prior to the chemical modification trials.

Preweighed amounts of oven-dry red oak and hard maple flakes were separately treated in a heated pressure chamber using one of the following chemical/pressure/time conditions:

Chemical pretreatments — water, NaOH (0.25 and 0.5%) and CH_3COOH (2 and 4%)
Digester pressure — 10 and 30 psi
Treatment time at pressure — 0 and 30 minutes
Liquor to wood — 35:1

For the zero minutes treatment time, the flakes were treated in the digester until the digester pressure reached either 10 psi or 30 psi. As soon as the digester reached the treatment pressure, the treatment was discontinued (0 minutes) or the treatment was continued for 30 minutes. Chemical concentrations used were: 0.25% sodium hydroxide (8.75 g NaOH pellets in 3,500 g water); 0.5% sodium hydroxide (17.5 g NaOH pellets in 3,500 g water); 2% acetic acid (70 g glacial

TABLE 1. *Summary of the average property values for aspen, red oak, and hard maple control flakeboards.*[1]

Species	Density lb/ft³	Bending MOE 10³ psi	Bending MOR psi	IB psi	Thickness swell (%) 2 H	Thickness swell (%) 24 H	Water absorption wt (%) 2 H	Water absorption wt (%) 24 H	Linear expansion (%)
Aspen	45.9A	520.3A	4,900A	38.9B	24.9A	32.5A	85.2A	102.5A	0.27A
Red oak	43.0A	404.8B	3,590B	131.8A	18.3B	20.4B	54.0B	67.4B	0.19A
Hard maple	44.5A	429.6B	4,140B	98.4A	19.2B	20.6B	50.1B	72.0B	0.26A

[1] Means with same letter are not significantly different at the 0.05 level.

acetic acid in 3,430 g water); and 4% acetic acid (140 g glacial acetic acid in 3,360 g water). The treatment temperatures ranged for water from 81 C (10 psi—0 min) to 118 C (30 psi—30 min), for 0.25% sodium hydroxide from 90 C (10 psi—0 min) to 124 C (30 psi—30 min), for 0.5% sodium hydroxide from 92 C (10 psi—0 min) to 124 C (30 psi—30 min), for 2% acetic acid from 83 C (10 psi—0 min) to 119 C (30 psi—30 min) and for 4% acetic acid from 86 C (10 psi—0 min) to 118 C (30 psi—30 min). The pretreated flakes were rinsed once and oven-dried, weighed, then conditioned to 6% EMC prior to fabrication into flakeboards.

Two flakeboards were prepared from each flake pretreatment condition. Untreated aspen, red oak, and hard maple flakes were used to make flakeboards for control and comparative purposes. All boards were manufactured under the following conditions:

Panel size (trimmed) — 16″ × 16″ × ¼″
Board density (target) — 42 pcf (673 kg/m²)
Resin — 7% phenolic based on OD wood weight
Additives — none
Press conditions — 320 F, about 44 sec to stops, 7 min total press time

The study was designed to investigate relative changes in board properties from each species associated with modification of high density hardwood flakes in contrast to untreated aspen, red oak, and hard maple boards. Flakeboard density, bending properties—modulus of elasticity (MOE) and modulus of rupture (MOR), internal bond (IB) and dimensional stability—linear expansion (oven-dry to 90% RH), and thickness swell (ASTM D1037) were determined on all experimental flakeboards. Analysis of variance tests were used to determine significant differences (0.05 level of significance) among the apsen, red oak and hard maple control flakeboards and for comparison of the treated and untreated flakeboard properties within a species.

RESULTS AND DISCUSSION

The aspen flakeboard controls had significantly higher bending properties, but lower IB properties than the red oak and hard maple control boards (Table 1). Higher thickness swell and water absorption properties were also measured for aspen control boards. However, no statistical differences in linear expansion values were measured on control boards made from the three wood species. Some of the strength and dimensional stability differences in the control boards may be attributed to density differences and flake geometry. While all of the species were flaked in the same manner, the aspen and hard maple tended to produce rect-

angular flakes, and the red oak produced a flat needle shaped flake. However, all control boards had acceptable properties compared to those reported by Carll (1986).

Red oak and hard maple flakes were modified using water, sodium hydroxide, and acetic acid in different pressure/time combinations (10 psi for 0 min, 10 psi for 30 min, 30 psi for 0 min and 30 psi for 30 min). During the treatments, the flakes were brought to pressure (10 psi or 30 psi) and the treatment was stopped (0 min) or the pressure was held at a designated pressure level for 30 min. Within each treatment pressure/time combination, the weight loss of the flakes in different charges varied. Since the ranges in weight loss for the different treatment combinations overlapped, particularly in the 10 psi for 0 and 30 min treatments, only the combined average weight loss values per chemical treatment were evaluated (Tables 2 and 3). Definitive statements about weight loss for different pressure/time combinations were difficult to determine and additional research is continuing to establish more clearly the weight loss effects on board properties.

The effects of the sodium hydroxide and acetic acid treatments on the average weight loss of red oak and hard maple flakes produced different results for the two species (Tables 2 and 3). Results show that alkali pretreatments had a higher average flake weight loss for both species compared to water and acetic acid pretreatments. At comparable sodium hydroxide pretreatment conditions, the average weight loss was higher for red oak than for hard maple flakes.

It is interesting to note that percent weight loss did not correlate well with the reduction in time for press closing during board fabrication. An improvement in press closing time was observed for all pretreated hard maple flakes, whereas only a slight reduction in press closing times was observed for alkaline pretreated red oak flakes. Apparently, extractives and/or wood substance removed during pretreatment had a significant effect on press closing times for hard maple compared to red oak.

An evaluation of strength properties of boards made from pretreated flakes showed, that compared to control boards, some differences in strength properties were observed (Tables 2 and 3). Statistically ($P \leq 0.05$) lower MOE, MOR, and IB properties within a species were measured in alkali-treated flakeboards (0.25% and 0.5% NaOH levels) compared to the control boards made for that species. However, with the exception of MOE for the 4% acetic acid pretreatments, no statistical differences in MOE, MOR, and IB properties were measured in acetic acid-pretreated red oak flakes compared to red oak control boards. A higher number of statistical differences in bending properties were found in hard maple flakeboards. All pretreatments significantly weakened the bending properties of hard maple compared to control boards. Water pretreatments of both red oak and hard maple flakes surprisingly appeared to reduce board strength properties more than acetic acid pretreatments. However, some of these differences could be explained on the basis of board density differences observed between hard maple boards (Tables 2 and 3). No statistical differences in IB properties for the controls and acetic acid-treated boards were measured for the red oak and hard maple specimens. For both species, the alkali pretreatments significantly reduced the IB values compared to the controls. In general, it appears that water pretreatments affected the bending properties of hard maple more than red oak flakes. Hard maple IB values were affected by all treatments more than red oak IB values.

TABLE 2. *Summary of the average property values for red oak flakeboards made with modified flakes.*[1]

Treatment	% Wt loss	% Red press closing	Density lb/ft³	Bending		IB psi
				MOE 10³ psi	MOR psi	
Controls			43.0A	404.8A	3,590A	131.8A
Water	4.97	0	41.6A	322.8BC	2,980BC	96.6A
2% Acetic	5.16	0	42.7A	358.9AB	3,420AB	106.7A
4% Acetic	5.74	0	41.4A	342.0B	3,220AB	106.8A
0.25% NaOH	13.13	1.5	43.0A	257.0D	2,378D	46.1B
0.5% NaOH	17.77	1.5	43.5A	282.6CD	2,560CD	50.1B

[1] Means with same letter are not significantly different at the 0.05 level.

No statistical differences in linear expansion were observed among control, water and acetic acid-pretreated boards for both species (Tables 2 and 3). The alkali-treated flakes produced significant increases for both species in linear expansion values. Similar trends in both thickness swell and weight of water absorption were also measured for red oak after the 2- and 24-hour soak test periods. However, all pretreatments, except the thickness swell values for acetic acid pretreatments, significantly increased thickness swell and water absorption values for hard maple compared to controls.

SUMMARY

Red oak and hard maple flakes were modified with water, 0.25 and 0.5% sodium hydroxide, and 2 and 4% acetic acid treatments prior to manufacture into panels. Flakes were treated with the mild chemical solutions at 10 and 30 psi for 0 and 30 minutes. Weight loss for both species can be controlled. Aspen and untreated red oak and hard maple panels were produced under the same flaking and manufacturing conditions and used as controls.

The results of the chemical treatments were different for red oak and hard maple. Hard maple panels exhibited a reduction in press closing time for all treatment levels compared to control boards for the three species, while red oak press closing time reduction was evident only for very high weight loss values.

Mechanical properties were reduced for both species as a result of all treatments. However, the reduction in mechanical properties for both species was less for the acetic acid treatments than either the sodium hydroxide or water treatments. The MOR values for acetic acid-treated red oak flakes were not significantly different from red oak control values.

TABLE 3. *Summary of the average property values for hard maple flakeboards made with modified flakes.*[1]

Treatment	% Wt loss	% Red press closing	Density lb/ft³	Bending		IB psi
				MOE 10³ psi	MOR psi	
Controls			44.5A	429.6A	4,140A	98.4A
Water	3.85	11	39.1C	271.4C	2,130D	35.1BC
2% Acetic	4.12	9	41.2B	344.5B	3,263B	46.8AB
4% Acetic	4.22	9	41.1B	325.6BC	2,980BC	49.4AB
0.25% NaOH	11.98	10	43.2AB	327.9BC	2,853BCD	24.9C
0.5% NaOH	14.24	12	42.7AB	275.8BC	2,390CD	19.4C

[1] Means with same letter are not significantly different at the 0.05 level.

TABLE 2. *Extended.*

Thickness swell (%)		Water absorption wt (%)		Linear expansion (%)
2 H	24 H	2 H	24 H	
18.3B	20.4B	54.0AB	67.4B	0.19A
16.9B	24.3B	37.3B	81.5B	0.22A
18.5B	23.2B	47.2B	86.2B	0.22A
16.9B	22.6B	45.1B	81.6B	0.24A
33.2A	39.0A	75.0A	119.0A	0.27B
29.0A	38.5A	69.8A	110.8A	0.31B

Water and acetic acid treatments for red oak produced comparable dimensional stability values. This indicated that weight loss may not be detrimental to the dimensional stability of the panels.

Red oak and hard maple control panel properties compared favorably with the aspen controls. Some properties of acetic acid-treated red oak and hard maple panels also compared favorably with the aspen controls.

Reducing the weight of high density flakes may provide a means to control some of the variability in mixed species furnished for particleboard. The treated flakes may also provide a means to improve preservative treatment of panels constructed with species that may be hard to treat with a preservative. This work shows that a weight loss can be controlled without detriment to many of the panel properties constructed with a high density hardwood species.

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TABLE 3. *Extended.*

Thickness swell (%)		Water absorption wt (%)		Linear expansion (%)
2 H	24 H	2 H	24 H	
19.2C	20.6B	50.1C	72.0C	0.26A
33.8A	39.3A	86.1B	97.7B	0.25A
25.7B	27.1B	82.6A	96.9B	0.25A
22.8B	25.2B	80.5B	93.2B	0.25A
31.8A	47.4A	114.6A	120.7A	0.32B
32.6A	48.5A	122.7A	127.9A	0.40B

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