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Section 4 Properties and Processes

Treatability problems—Relationships between anatomy, chemical composition and treatability

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ABSTRACT
This report documents the results of phase 1 and 2 of a 3-phase research program. In phase 1, two hundred and fifty-six (256) Southern pine (*pinus spp.*) nominal 2 x 6's (38 mm x 140 mm) from a single mill in Georgia (southeastern US) were evaluated for treatability with CCA preservative. After treatment, 128 pieces representing a broad range of treatment characteristics were selected and more fully evaluated for anatomical and chemical composition. No direct correlation was noted between CCA treatability and any of the anatomical characteristics evaluated in this study. Neither did a direct correlation between chemical composition and treatability seem to exist. The pit tori of all pits evaluated in this study were aspirated against the pit wall for this difficult to treat Southern pine lumber. This pit aspiration might have resulted from pre-treatment kiln drying. Later reductions in kiln temperature and increased kiln humidity (i.e., lowered wet-bulb depression temperature) reportedly resulted in improved treatability. In Phase 2, a methodology was developed to assess treatability after 3 treating schedules and then compare those results to permeability measurements and anatomical characteristics of matched material from 7 growth regions.

Keywords: Penetration, Treatability, Anatomy, Chemical Composition, Preservative, Treatment

INTRODUCTION

Recently, reports have surfaced of unexplained variability in treatability for material believed to consist of mono-species groupings. We know that wood permeability in Loblolly pine is related to position in tree and juvenility (Milota et al 1995). We also know that some whitewood producers are now using dry-kiln schedules approaching 150°C (300°F). Thus, we suspected that variation in treatability, especially when using modified full-cell schedules, might be related to the combined influence of variations in wood permeability, juvenility, and in primary-processing regimes. This suggests that changes in processing by "Whitewood producers", especially thermal-intensive processing such as pre-treatment kiln drying, may affect the chemical composition, which might account for variations in treatability.

Southern pine sapwood is a preferred wood species to pressure treat with preservatives because it has high-sapwood contents and it is relatively permeable. Southern pine is really a commercial species marketing grouping of four major pines (Loblolly *Pinus taeda*, Slash *P.elliotii*, Longleaf *P.palustris* and Shortleaf *P.echinata*). Each of these four major species has subtly different levels of treatability. This was pointed out by Jewell *et al* (1990) and Taylor (1991), who both showed that shortleaf was more difficult to treat than loblolly. They also suspected, but could not prove, that high-temperature kiln-schedules (>150°C (300°F)) might influence treatability.

BACKGROUND

A significant amount of research has recently proven that changes in the chemical composition of the wood material can be directly related to strength losses from thermal degrade in fire-retardant-treated, CCA-treated, and untreated wood (LeVan et al 1990, Winandy 1994,1995). This relationship between wood chemistry and strength has also been shown for bio-induced degradation via brown-rot decay of wood (F.Green et al 1991, Winandy and Morrell 1993, Son et al 1995). This work has consistently shown that degradation is related to changes in the hemicellulose structure. In particular it has shown that side-chains of hemicellulose, such as arabinans and galactans, are degraded prior to main-chain units of the hemicellulose, which is primarily xylans or mannan-glucans, which in turn are degraded prior to cellulose or lignin.

PROBLEM

It is logical to assume that processing-induced variations in treatability might be linked to changes in chemical composition resulting from accumulated thermal decomposition during pre-treatment processing and kiln drying. Variations in pit-aspiration could also be related to wood's accumulated thermal-processing history, especially at temperatures above 150°C (300°F). This has serious implications because no systematic pit aspiration data or chemical composition data exists for wood dried at kiln-drying temperatures above 115°C (240°F). Pre-treatment thermal processing is likely affecting both the chemical composition of wood and the proportion of permanently aspirated pits in wood intended for preservative treatment. A more complete understanding of pit aspiration and the factors controlling the permanency of pit aspiration are needed to predict subsequent treatability.

METHODS AND MATERIALS

Cooperating with a preservative treating plant in Georgia, we evaluated the treatability of 256 pieces of 4.9 m (16-ft.) nominal 2 x 6, No.2 Prime, Southern pine lumber obtained from a single sawmill in Georgia that had been reported by several treaters as more difficult to treat than lumber from other nearby pine sawmills. No. 2 Prime is a special grade used as decking material in the United States that allows for very little wane. For each of the 256 pieces evaluated, the 4.9 m (16-ft.) board was cut in half and each half was identified. One half of each nominal 2 x 6 was then treated with CCA Type C using a modified full-cell treatment with a 30-minute pressure period followed by a 100% inspection of penetration. We found 102 out of 256 assays evaluated failed to meet the AWPA Standard C-2 (AWPA 1999) specified penetration requirements. We then went to the matched untreated 2.4 m (8-ft.) halves and selected the 102 failures and 26 representative specimens that did treat acceptably. They shipped the 102 untreated "failures" and 26 untreated "representative" specimens to FPL for further evaluation in this study.

At FPL, visual evaluations of various anatomical characteristics such as percent heartwood, percent juvenile wood, presence of pith, growth rate, or presence of fungalinduced blue stain were performed. Carbohydrate composition was evaluated by high-pressure liquid chromatography (Pettersen and Schwandt 1991). About one-quarter of the 128 untreated 2.4 m (8-ft.) half-sections of the 4.9 m (16-ft.) lumber were randomly selected. The porosity of pit membranes was evaluated on 12 mm (1/2-in.) cores removed from those specimens using the technique of Milota *et al* (1995). The integrity of the pit membrane in each core was visually evaluated using a light microscopic and the relative pit aspiration assessed.

RESULTS

Phase 1

The carbohydrate content of a series of 24 randomly selected specimens (17 which failed and 7 which were accepted under the AWPA *Standard C-2* penetration requirements) was evaluated using high-pressure liquid chromatography. These results clearly show that for this single-mill sample, no practical differences existed in carbohydrate content between Southern pine which was judged as treated using treatment penetration criteria from AWPA *Standard C-2* versus that which did not treat (Table 1).

Individual evaluations of various anatomical factors, such as percent heartwood, percent juvenile wood, presence of pith, growth rate, or presence of blue stain, are also shown in Table 2. No direct correlation was noted between treatability and any of the anatomical evaluations in this single-mill survey. The lack of any direct correlation between chemical composition and treatability is shown in Figure 1.

The microscopic evaluation of pit structure showed that the membranes of 100% of pit tori evaluated were aspirated against the pit wall for this difficult to treat Southern pine lumber. It is not clear why the pit membranes were nearly all aspirated, but it is logical to assume that the primary sawmill and drying process somehow was at least partially responsible. It is interesting to note that when informed of these results, the original sawmill and kiln-drying facility lowered their direct-fire kiln temperatures by 5-10°C (9-18°F) and closed their top-vents, which effectively increased the humidity within the kiln during drying. A few months later, personnel from our cooperating treating plant and other nearby treating plants commented to us that dramatically fewer treatment penetration failures where noted for lumber from this particular sawmill after the sawmill altered its kiln schedule. We are continuing our study of this phenomenon.

Longitudinal gas permeability was also measured between heartwood and sapwood sections on matched specimens. The relative ratio of sapwood/heartwood permeability was between 0.71-0.95 with one exception in which the permeability ratio was 0.41 but that specimen had larger and more numerous (approx. 4x times more) resin canals than the others. Our microscopic evaluation also sometimes found there may be a zone of "transition wood" that is one or two growth increments wide between true sapwood and heartwood. Sano and Nakada (1998) have previously reported similar findings for *Cryptomeria japonica*. The transition zones we observed between true heartwood and sapwood in Southern pine showed indications of partial pit incrustation by phenolics. This pit incrustation might impede CCA penetration by blocking the pits of Southern pine. This encrustation might be influenced by kiln-temperature and relative humidity, which would influence moisture flux and internal pressures.

Sample	**Met AWPA Requirements**	**Arabinan (%)**	**Rhamnan (%)**	**Galactan (%)**	**Xylan (%)**	**Mannan (%)**	**Glucan (%)**	**Carbo-Hydrate (%)**
13	**Fail**	1.12	0.10	2.07	5.40	12.4	41.4	62.5
22	**Fail**	1.26	0.10	1.89	6.79	10.2	41.9	62.1
27	**Fail**	1.14	0.07	1.34	5.80	12.0	44.4	64.8
28	**Fail**	1.14	0.09	1.87	5.95	11.2	42.8	63.1
35	**Fail**	1.15	0.09	1.39	6.39	11.6	43.2	63.9
40	**Fail**	1.10	0.10	1.53	5.23	11.7	44.5	64.2
57	**Fail**	1.23	0.11	1.66	5.50	12.2	42.6	63.2
58	**Fail**	1.15	0.08	2.05	6.12	11.1	42.8	63.4
63	**Fail**	1.13	0.09	1.71	6.64	10.1	42.7	62.4
65	**Fail**	1.06	0.10	2.08	5.95	11.5	42.5	63.2
67	**Fail**	1.17	0.08	1.55	5.21	11.2	44.3	63.6
94	**Fail**	1.12	0.07	2.95	5.78	10.7	42.5	63.1
145	**Fail**	1.35	0.14	2.81	6.98	9.8	40.4	61.5
156	**Fail**	1.14	0.08	1.57	5.26	12.7	42.9	63.6
181	**Fail**	1.14	0.11	1.77	5.66	12.1	41.8	62.6
186	**Fail**	1.27	0.11	1.67	6.34	10.6	43.0	62.9
217	**Fail**	1.40	0.11	1.53	6.69	11.2	39.2	60.1
1	**Pass**	1.30	0.11	2.64	6.39	10.1	41.4	61.9
4	**Pass**	1.26	0.10	2.46	7.03	9.9	39.8	60.6
18	**Pass**	1.28	0.10	1.99	6.73	10.8	41.0	62.0
21	**Pass**	1.19	0.09	2.02	5.51	10.9	40.9	60.7
31	**Pass**	1.13	0.08	1.47	6.56	10.5	42.9	62.6
71	**Pass**	1.18	0.09	2.13	5.59	11.1	43.1	63.1
252	**Pass**	1.14	0.10	2.36	6.30	11.0	41.9	62.8

Table 1—Chemical composition of 17 treatable and 7 untreatable specimens

Sample	Met AWPA Requiremtnts	Juvenile Wood (%)	Pith Present	Heartwood (%)	Rings/inch	Blue Stain
13	**Fail**	70	Yes	65	4	No
22	**Fail**	60	Yes	0	4	No
27	**Fail**	0	No	0	8	Yes
28	**Fail**	60	Yes	0	7	No
35	**Fail**	80	Yes	0	5	No
40	**Fail**	0	No	0	9	Yes
57	**Fail**	0	No	0	7	Yes
58	**Fail**	70	Yes	50	9	No
63	**Fail**	60	Yes	25	6	No
65	**Fail**	70	Yes	0	11	No
67	**Fail**	60	Yes	30	10	No
94	**Fail**	70	Yes	0	6	No
145	**Fail**	80	Yes	20	5	No
156	**Fail**	0	No	0	10	Yes
181	**Fail**	80	Yes	0	5	No
186	**Fail**	0	No	0	5	Yes
217	**Fail**	0	No	0	4	Yes
1	**Pass**	0	No	0	12	No
4	**Pass**	50	Yes	0	4	No
18	**Pass**	60	Yes	0	5	No
21	**Pass**	60	Yes	15	5	No
31	**Pass**	70	Yes	0	7	No
71	**Pass**	0	No	0	8	No
252	**Pass**	80	Yes	60	13	No

Table 2- AWPA Standard C2 penetration limits and anatomical evaluation.

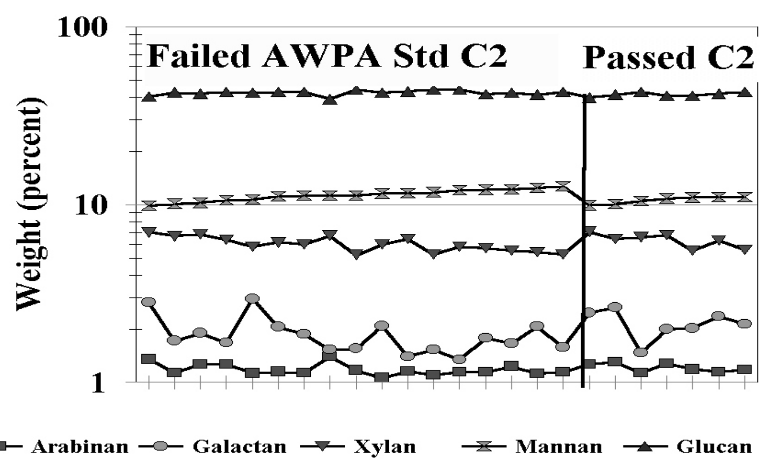


Figure 1. Comparison of chemical composition of 24 randomly selected samples of Southern pine 2x6 lumber of which 17 failed and 7 passed the AWPA Standard C-2 penetration requirement.

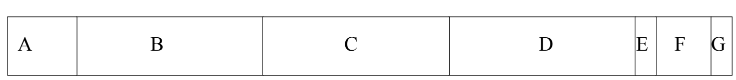
Phase 2

Currently in Phase 2 of this program, additional Southern pine lumber is being sampled from the various major growth-regions for all four major Southern pines. For each species, the influence of various kiln-drying scenarios on treatability will be evaluated. Concurrently, that material will be evaluated for changes in initial chemical structure and composition. The influence of this pre-treatment processing on transverse permeability will also be evaluated. Further, cellular pit-membranes will be microscopically and chemically evaluated to identify changes in aspiration and chemical composition. Data from chemical composition, transverse permeability, cellular pit-structure and level of pit-aspiration will be combined and jointly analyzed to understand the relative influence of each factor on treatability.

In preliminary work under Phase 2, two nominal 2x 6, 1.2 m (4-ft.) long samples were obtained from each of 7 distinct Southern pine growth regions (Table 3). The lumber was shipped to FPL and cut-up as shown in Figure 2. As with the previous work no difference were noted in our anatomical inspections. Pit membrane structure was not assessed, but will be in Phase 2. The chemical composition of these materials from 7 growth regions showed no discernable differences (Figure 3). Our visual analysis of differential preservative penetrations patterns between full-cell, modified full-cell, and low-weight CCA-treatments showed few apparent differences (Figure 4).

Mills	Location	Growth Area
A	Georgia	Coastal
B	Florida	Piedmont
C	South Carolina	Piedmont
D	Georgia	Coastal
E	Georgia	Coastal
F	Georgia	Coastal
G	Arkansas	Ozark Highland

Table 3. Key to sampling regions in preliminary work in Phase 2 of this program.



A - 5” Permeability
B - 12” Treatability A-Full (ends were sealed)
C - 12” Treatability B-Modified Full (ends were sealed)
D - 12” Treatability C-Low-weight (ends were sealed)
E - 1” Chemical Analysis
F - 4” Anatomy Specimen
G - 1” Specific Gravity/Moisture Content

Figure 2. Cut-up pattern for 1.2 m (4-ft) Southern pine lumber

SUMMARY

We evaluated the relationship between anatomy, chemical composition, and preservative treatability for 256 pieces of Southern pine lumber obtained from one sawmill in Georgia (southeastern US). This material was classified through previous experience as more difficult to adequately treat than lumber from other nearby sawmills. No direct correlation was noted between CCA treatability and any of the anatomical characteristics (percent heartwood, percent juvenile wood, presence of pith, growth rate, or presence of blue stain) evaluated in this study. Neither did a direct correlation between chemical composition and AWPA Standard C-2 required treatability seem to exist.

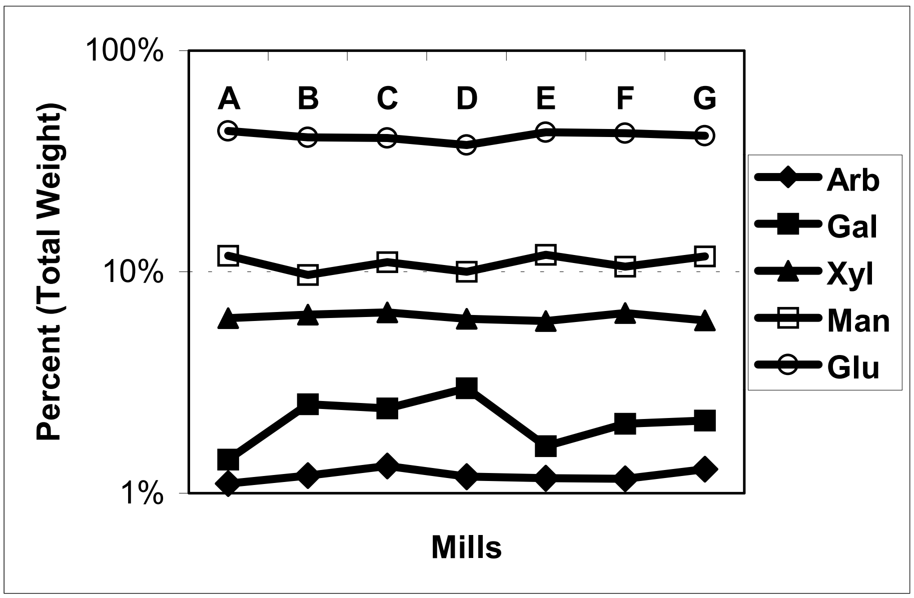
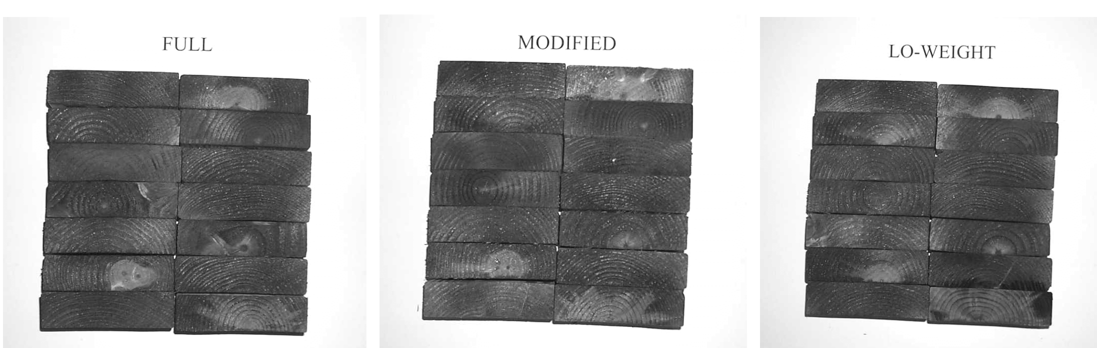


Figure 3. Chemical composition of 1.2 m (4-ft) long, nominal 2 x6 Southern pine lumber from 7 different sawmills. Key to Letter designations in figure are given in Table 3



(a) Full-Cell Treatment (b) Modified Full-Cell Treatment (c) Low-weight Treatment

Figure 4- CCA penetration patterns of two replicate 2x6 Southern pine pieces from 7 different Mills (vertical) after full-cell, modified full-cell, and low-weight treatments. Mills A-F are shown stacked in order from top (A) to bottom (F) with each replicate shown side-by-side..

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