FIBERBOARDS MADE FROM ACETYLATED BAGASSE FIBER

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ABSTRACT

Bagasse fiber was acetylated with acetic anhydride alone to various levels of acetyl weight gain. Acetylation causes the bagasse fiber to become more hydrophobic, as evidenced by a lowering of the equilibrium moisture content as the level of acetylation increased. Acetylated bagasse fiber and fiberboards made from acetylated fiber at acetyl weight gains of about 17% had an equilibrium moisture content of about one-third that of controls at all relative humidities tested. Fiberboards made from acetylated fiber swelled at a much slower rate and to a lesser extent as compared to control fiberboards. Internal bond strength was higher in acetylated fiberboards, while moduli of rupture and elasticity were slightly lower in acetylated boards than in control boards.

Keywords: Bagasse, acetylation, fiberboards, water swelling, strength properties, equilibrium moisture content.

INTRODUCTION

About 54 million dry tons of bagasse, the fibrous byproduct remaining after sugar extraction from sugarcane, is produced annually throughout the world. Bagasse is used either as a fuel by the sugar factory or as a raw material for the manufacture of pulp and paper products, various types of building boards, and certain chemicals.

Pulp produced from bagasse is used in such products as facial and toilet tissue, various types of writing and printing papers, bag and wrapping papers, Bristol board, corrugating medium, and linerboard. These represent only a small fraction of the total bagasse produced.

Several board products are presently made from bagasse. Softboard, with a density of about 380 kg/m^3, made by a wet process, is used mainly in acoustical tiles. A medium-density fiberboard or particleboard, with a density of about 760 kg/m^3, is also produced by dry processing. A high-density hardboard, with den-

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sities up to approximately 1,140 kg/m^3, is also produced by a wet process. As with the pulp-derived products, only a small fraction of the byproduct bagasse is utilized in board products.

The chemical composition of bagasse is similar to that of hardwoods, so fiberboards made from bagasse fiber and fiberboard made from hardwood fiber have similar properties. One problem that has limited the use of fiberboards for many applications is swelling due to sorption of water. Acetylation of hardwood and softwood fiber, particles, and flakes greatly decreases swelling in reconstituted wood products (Rowell 1984). Acetylation takes place in the wood cell-wall polymer, and the bulking effect of the acetyl group keeps the wood in a partially swollen state. When the wood does come into contact with water, little additional swelling can take place. Acetylation of wood also greatly improves biological resistance because of the reduced moisture sorption and substrate blocking in the reacted cell-wall polymers (Nilsson et al. 1988).

Since bagasse is similar in chemical composition to wood, it should be expected that bagasse would react with acetic anhydride and that the properties of acetylated bagasse would be much the same as the properties of acetylated wood.

The purposes of this research were (1) to determine whether bagasse fiber could be acetylated by a fast, simple acetylation procedure, (2) to determine moisture sorption properties of acetylated fiber, and (3) to make fiberboards from control and acetylated fiber and determine swelling and mechanical properties on the boards.

EXPERIMENTAL

Bagasse fiber

Bagasse from a countercurrent diffusion extractor with a five-roller dewatering mill in Hawaii was screened to remove fines and was dried to 30% moisture for storage. Prior to reaction the bagasse was run through a hammer mill and dried for 4 h at 105 C.

Reaction of fiber with acetic anhydride

Oven-dry bagasse fiber was placed in a stainless steel mesh container. The container was dipped into a tank containing 25 C acetic anhydride for 1 min, removed from the treating tank, and drained for 3 min at 25 C. The container with the wetted fiber was placed in a preheated (120 C) stainless steel reactor for various lengths of time, after which vacuum was applied to the reaction cylinder for 1 h at 120 C. A condenser on the bottom of the reactor collected excess acetic anhydride and byproduct acetic acid. The acetylated fiber was then reoven-dried for 12 h at 105 C. The weight percent gain (WPG) due to acetylation was calculated based on the weight of oven-dried unreacted fiber.

Leaching and acetyl content of acetylated fiber

Weighed oven-dried samples of control and acetylated fiber were leached under two conditions: (1) 14 days in distilled water at 24 C (changing water every 24 h) or (2) 2 h in a Soxhlet extractor with refluxing toluene/ethanol (1/1, v/v). Samples were weighed after reoven-drying.

Acetyl content was determined before and after leaching by gas chromatography

following deacetylation of ground and mixed samples with sodium hydroxide solution.

Fiberboard production

Control or acetylated fiber was sprayed with a 5% (based on the oven-dry weight of the fiber) aqueous solution of a phenol-formaldehyde resin. The fiber was hand-formed into 60- by 60-cm randomly oriented mats. Control and acetylated boards were pressed to a maximum thickness of 1.25 cm for 8 min at 185 C. All boards had an approximate density of 640 kg/m^3 and were trimmed to a final size of approximately 55 by 55 cm.

Equilibrium moisture content

Equilibrium moisture content (EMC) of control and acetylated fiber and fiberboards was determined by placing weighed, oven-dried fiber or fiberboards in constant humidity rooms at 30%, 65%, and 90% relative humidity (RH) and 27 C. After 21 days, fiber and fiberboards were reweighed and EMC determined. Duplicate tests were run and values averaged.

Water swelling tests

Each fiberboard specimen (51 by 51 mm) was placed in a 10- by 10-cm container, 5 cm deep. The container was on a flatbed micrometer for the thickness measurements. Water was added to the container and the thickness recorded as a function of time. Measurements were taken every 5 min for the first hour, every hour for the first 6 h, then once a day for 5 days. All water tests were done in duplicate.

Water soaking tests

Cyclic water soaking tests were run on boards (51 by 51 mm) as previously described (Rowell and Ellis 1978). Each of six cycles consisted of water soaking for 5 days followed by oven-drying at 105 C for 2 days. Thickness swelling was calculated as a percentage of the original oven-dried thickness.

Strength properties of fiberboards

Static bending tests were conducted on board specimens (76 by 330 mm) according to American Society for Testing and Materials standard D 1037 (ASTM 1982), using a 300-mm span. Moduli of rupture (MOR) and elasticity (MOE) were determined.

Internal bond (IB) tests (ASTM D 1037) were carried out with specimens (51 by 51 mm) cut both from fiberboards for this purpose only and from the ends of specimens broken in static bending.

RESULTS AND DISCUSSION

Reactivity

Weight percent gain from acetylation of bagasse fiber as a function of reaction time is shown in Fig. 1. At 2-h reaction time, bagasse had about a 16 WPG, which did not increase significantly after 2 h more of reaction.

The rates of acetylation of aspen (Rowell et al. 1986b) and pine (Rowell et al.

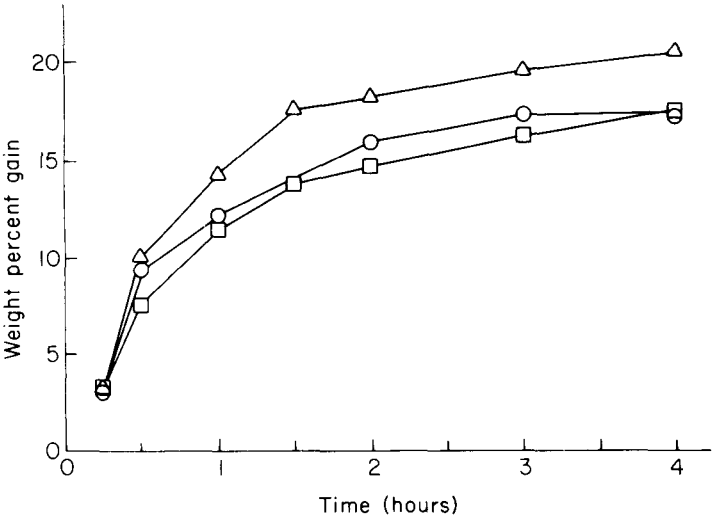

FIG 1. Degree of acetylation of bagasse fiber and aspen and pine wood flakes as a function of reaction time (120 C). O, bagasse fiber; □, aspen flakes; △, pine flakes. (ML87 5329).

1986a) flakes are also shown for comparison. Bagasse acetylated at about the same rate as aspen, both somewhat more slowly than pine. The chemical compositions of bagasse, aspen, and pine (Table 1) are very similar, and because of the small size of each (fiber or flakes), accessibility of the reacting chemical to available cell-wall hydroxyl groups is not a reaction limitation.

Leaching tests

Water leaching for 14 days at 24 C caused less weight loss in acetylated bagasse fiber than in unreacted fiber (Table 2). This may result from the leaching of water-soluble components by the acetic anhydride dipping solution and during the vacuum removal of excess anhydride and byproduct acetic acid. More weight loss in acetylated bagasse fiber was seen in Soxhlet extraction for 2 h in toluene/ethanol, especially at the highest WPG (17.6). Only a slight loss of acetyl content was observed in either water or toluene/ethanol, indicating that whatever is extracted from the fiber has about the same acetyl content as the remaining fiber.

Equilibrium moisture content

Table 3 shows that at each RH tested, the EMC for acetylated bagasse fiber and fiberboards decreased as the weight gain due to acetylation increased. The

TABLE 1. *Approximate chemical composition of bagasse fiber and aspen and pine wood flakes.*

	Chemical content (weight %)					
	Holo-cellulose	Cellulose[a]	Pentosans[b]	Lignin[c]	Extractives[d]	Ash
Bagasse	78	43	25	20	2.1	0.7
Aspen (*Populus tremuloides*)	75	49	19	19	3	0.4
Pine (*Pinus sylvestris*)	66	45	12	27	4	0.3

[a] Alpha cellulose.
[b] Total xylose and arabinose.
[c] Klason lignin.
[d] Soluble in ethanol/benzene.

TABLE 2. *Effect of leaching on control and acetylated bagasse fiber.*

Acetylation weight percent gain	Acetyl content before leaching (%)	Effect of leaching (%)			
		Water leaching[a]		Toluene/ethanol leaching[b]	
		Weight loss	Acetyl content	Weight loss	Acetyl content
0	3.4	6.7	3.5	3.8	3.4
9.4	14.4	4.7	12.2	4.7	11.3
12.2	15.3	3.3	15.3	5.6	13.8
16.0	17.2	4.0	17.8	3.4	16.3
17.6	19.0	1.4	19.2	6.3	17.8

[a] 14 days; 24 C.
[b] 2/1, v/v; reflux, 2 h.

EMC for the fiber and boards at 17.6 WPG were about one-third that of controls at each RH. Boards made from acetylated fiber at WPG values greater than 13 show a higher EMC at each RH than the acetylated fiber alone. This shows that the phenolic resin used was more hygroscopic than the acetylated fiber.

Water swelling

Figure 2 shows that the rate and extent of liquid water swelling of acetylated boards are greatly reduced compared to control boards. After only 15 min of water contact, control boards had swollen 19% in thickness, whereas the acetylated boards swelled less than 3%. At 5 days, control boards swelled almost 26% in thickness, and the acetylated boards swelled less than 5%.

Thickness changes in the repeated water swelling test are shown in Fig. 3. Irreversible swelling (caused by release of residual compressive stresses imparted to the fiberboard during pressing) and reversible swelling (normal wood cell-wall swelling) are both greatly reduced in boards made from acetylated fiber as compared to control boards.

Strength properties

Table 4 shows the mechanical properties of control and acetylated fiberboards. Internal bond strength is higher in acetylated boards than in controls, but both MOR and MOE are reduced in acetylated boards compared to control boards. Visual inspection of the failed samples from the IB test show that in many cases the failure occurs along a line of very fine particles. Screening of the bagasse fiber to remove fines would prevent this type of failure.

TABLE 3. *Equilibrium moisture content (EMC) of bagasse fiber and fiberboards at various relative humidities.*[a]

Acetyl weight gain (%)	EMC (%)					
	30% RH		65% RH		90% RH	
	Fiber	Board	Fiber	Board	Fiber	Board
0	4.4	3.8	8.8	7.6	15.8	17.1
3.1	3.3	—	6.5	—	12.4	—
9.4	2.0	—	5.3	—	9.5	—
13.0	1.7	1.8	4.4	4.0	7.7	8.0
16.0	1.4	1.8	3.4	3.9	6.6	8.0
17.6	1.4	1.8	3.4	4.0	5.8	7.9

[a] 27 C.

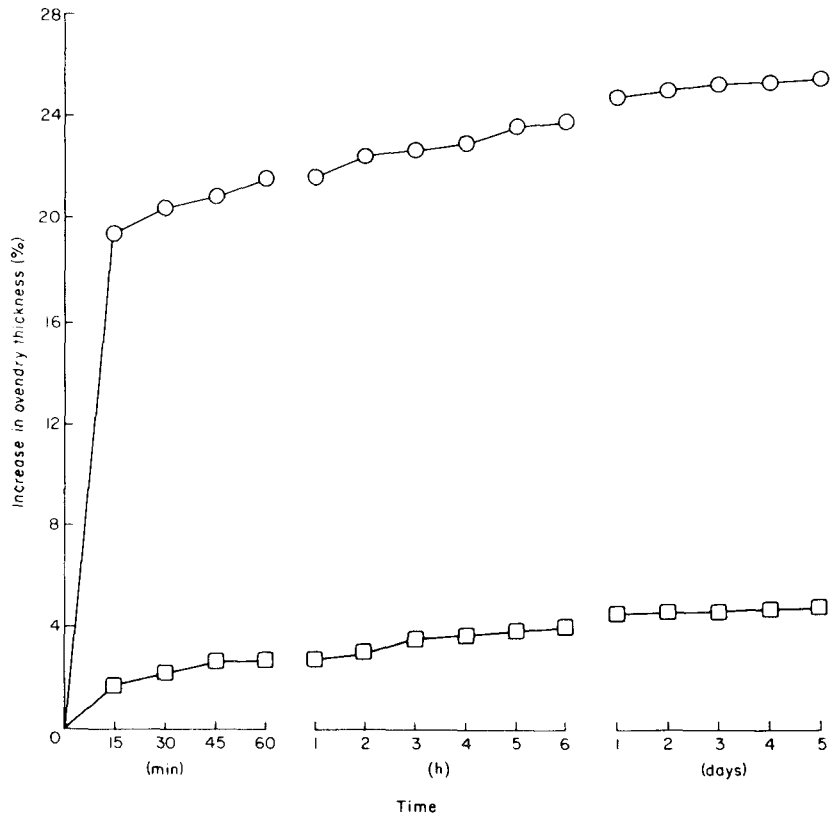

FIG. 2. Rate of swelling in liquid water of fiberboards made from control and acetylated bagasse fiber. O, control; □, 17.6 WPG. (ML89 5786).

CONCLUSIONS

The results of this study show that acetylation of bagasse fiber produces a more hydrophobic fiber whose EMC is significantly reduced as compared with unreacted fiber. Fiberboards made from acetylated fiber show greatly reduced rate and extent of thickness swelling, greatly reduced irreversible and reversible swelling compared to control boards. Mechanical properties of both control and acetylated boards are approximately the same. Any differences may be due to the distribution of fines in both types of boards.

Research is presently underway to determine biological resistance of fiberboards made from acetylated bagasse fiber and to study board properties as a function of fiber milling and screening.

TABLE 4. *Strength properties of fiberboards made from control and acetylated bagasse fiber.*[a]

Acetyl weight gain (%)	Internal bond (kPa)	MOR (MPa)	MOE (MPa)
0	310	13.9	1,399
13	469	12.1	1,275
17	489	11.5	1,158

[a] 5% phenolic adhesive.

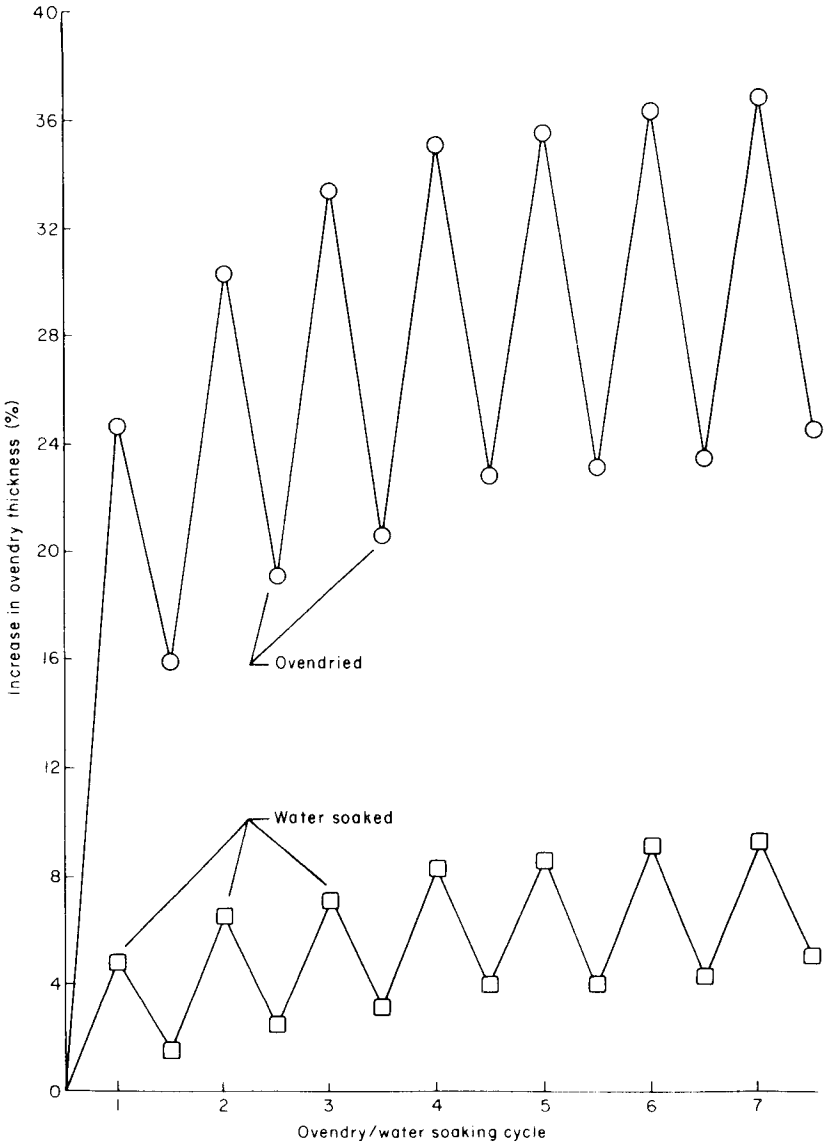

FIG. 3. Changes in thickness in repeated water swelling test of fiberboards made from control and acetylated bagasse fiber. O, control; □, 17.6 WPG. (ML89 5785).

This research should result in the production of a moldable composite made from acetylated bagasse fiber that will be strong, dimensionally stable, and biologically resistant.

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