Potential of Chicken Feather Fibre in Wood MDF Composites

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ABSTRACT: We made a series of aspen fibre medium density fibreboard panels adding various levels of chicken feather fibre to determine the relative effect of the feather fibre-wood fibre mixtures on composite panel properties. Chicken feathers are a waste product left over after processing chickens for meat. The feather fibre amounts used ranged from 20% to 95% and a 5% concentration of phenol formaldehyde resin was used as the adhesive. The panels were tested for mechanical and physical properties as well as decay. Initial mechanical properties show some loss in strength and stiffness for feather fibre-wood fibre mixtures when compared to the properties of all-wood control panels, but optimal resin chemistry and processing have yet to be studied. More importantly, the physical properties of feather fibre-wood fibre mixtures showed a marked improvement in resistance to water absorption and thickness swell over the control panels, probably related to the hydrophobic keratin in the feather fibre. Further testing is currently being done to determine the threshold(s) of feather fibre required to decrease thickness swelling and increase water-resistance. We are also studying ways to improve process and resin-fibre compatibility.

KEYWORDS: medium density fibreboard, chicken feather fibre, composite properties, durability

INTRODUCTION

Chicken feathers are a waste product left over after processing chickens in the food processing industry. Close to $2x10^9$ kg of chicken feather waste is generated in the US. each year [1]. Chicken feather fibre offers a large, cheap fibre market as an additive for medium density fibreboard (MDF). Chicken feathers are approximately half feather fibre and half quill (by weight). The feather fibre and quill are both made from hydrophobic keratin, a protein that has strength similar to nylon and a diameter smaller than wood fibre. The quills are used in shampoo, hair conditioner, hair coloring, and dietary supplements. The fibre is more durable and has a higher aspect ratio than the quill. Finding a high volume, high value use for feather fibre, a material most commonly land-filled or used for feed protein, would greatly benefit to the poultry industry and would add a fibre source for the wood industry.

The objective of this project was to make and study a series of medium density fibreboard panels containing several differing mixtures of wood fibre and chicken feather fibre (CFF) and to test various mechanical and physical properties of those panels. Our goal was to determine if the CFF had an effect on the properties of the composite panels and to determine if CFF could augment or improve selected performance properties of MDF. Two types of control panels, one set from only medium density fibreboard fibres and the second only from chicken feather fibre, were made and against which the experimental panels were compared. The wood fibre was obtained from a commercial MDF panel producer, the Georgia Pacific MDF plant in Phillips, WI. The feather fibre was removed from the feather quill by Featherfiber Corporation, Nixa MO using a USDA ARS patented process [2]. The quill-less CFF fibre was shipped to FPL. The adhesive used for the panels was a phenol formaldehyde (PF) oriented-strand board face resin provided by Dynea Resins, Inc. The experimental design is shown in Table 1.

Table 1. Experimental Design of study

Aspen Fibre(%)	Chicken Feather Fibre(%)	Resin(%)	Board structure
95	0	5	Single Layer
75	20	5	Single Layer
75	20	5	3 Layer CFF core
75	20	5	3 Layer CFF faces
47.5	47.5	5	Single Layer
0	95	5	Single Layer

Resin was applied to the furnish in a rotating drum blender. Both the aspen fibre and CFF were laid up in various combinations as a medium density fibreboard mat as indicated in Table 1 (see Figs. 1 and 2).

Fig. 1 various combinations evaluated of aspen wood fibre and CFF,

Fig. 2 examples of two pre-pressed MDF mats prior to pressing showing a uniform distribution of aspen fibre (left) and a three-layer mat with aspen fibre on faces and CFF in core (right).

Two replicate panels were made from each composition resulting in a total of 12 panels. The panels were 380 x 380 x 12 mm. Control panels were made with 95% aspen fibre and 5% resin and with 95% CFF and 5% resin. The panels were pressed at 200°C for approximately 240 seconds that we found in preliminary testing to be long enough to fully cure the PF resin. Following pressing, all panels were weighed and measured for determination of specific gravity. Spring-back of 12 mm-thick panels after 24-hour exposure at 23°C and 65% relative humidity was also recorded. The panels were cut into specimens following the spring-back measurements. The panels were cut into specimens for mechanical and physical testing as shown in Table 2. Water absorption and thickness swell was made at two hours and 24 hours from start of the test.

A newly developed test was used to determine the potential for the wood-CFF composites to support mould growth [5]. Test specimens were inoculated by whatever indigenous mould spores were present under ambient conditions. Mould coverage on each specimen was evaluated on the following scale based on percent of surface area covered with mould: None (N) zero mould, Light (L) - <10%, Moderate (M) 10-50%, or Severe (S) - >50% coverage.

Table 2. Tests and test specimen sizes and number

Test	Specimen size (mm)	Specimen per panel	Reference[2]
Bending MOE, MOR)	75 x 356	2	[3]
Internal Bond	50 x 50	4	[3]
Decay	19 x 19	4	[4]
Mould	75 x 356	2	[5]
Water Absorption[1]	150 x 150	2	[3]
Thickness Swell[1]	150 x 150	2	[3]

[1]Water absorption and Thickness swell tests are made from the same specimen.
'Reference numbers correspond to numbers in Reference section

RESULTS AND DISCUSSION

Mechanical property tests indicated real differences in the materials (Table 3). We found that addition of CFF to MDF had very little negative effect on internal bond (IB) strength. Single layer MDF board with 20% CFF had similar Modulus of Elasticity (MOE) and bending strength (MOR) to all wood fibre MDF. We believe that the differences in MOE and MOR between single layer MDF and the two types of 3 layer MDF are remnants of our processing and not related to an inherent difference between the varying board structures. It is also interesting to note that when CFF was used at an equal mixture with wood fibre that MDF had superior resistance in a 2-hour thickness swell (TS) test and in a water absorption (WA) test. These soak tests indicated that augmenting wood fibre with varying amounts of CFF may provide enhanced resistance to moisture for MDF and possibly other wood composites (Table 3).

CFF can be considered both hydrophilic and hydrophobic. At a molecular level, 39 of 95 amino acids in the keratin monomer are hydrophilic [6]. The most abundant amino acid in feather keratin is serine and each surface of serine has a corresponding free OH. Thus, CFF can absorb moisture from the air However, because they are such fine fibers, at a macroscopic level feather fibre has an inherent problem with wettability. Fibre is too fine to have enough surface force to bend water. Water droplets will bead on clean feather fiber. If one uses a fine mist, moisture will be adsorbed, and once wet, it takes extra force to dry the fibers wet at these hydrophilic sites. It may also be that if the PF resin binds to most of the exposed serine sites, the remaining sites on CFF would be hydrophobic. In future work, if we can optimize ow processing of the keratin-resin reaction instead of the wood resin reaction, it may be possible to realize an even greater level of moisture-resistance and property enhancement for the blended wood-CFF composite. Fiber to fiber, the keratin in CFF is tougher than cellulose, but cellulose has a higher concentration of -OH binding sites on a mole fraction basis.

Decay tests indicated other benefits may exist from using some CFF, and should be further examined, in the decay-resistance of these materials (Table 4). It seemed that CFF, at an equal mixture with wood fibre, imparted some decay resistance against both brown and white rot fungi. This trend was further supported by the relatively high-decay resistance of MDF with just CFF in the faces where the MDF was in direct contact with the decaying feeder strip. The CFF-rich faces seemed to inhibit subsequent decay in the wood fibre core.

We also evaluated the potential for surface mould to occur on MDF when exposed to a high-humidity environment, but not in direct contact with water (Table 4). In Table 2, a group rating of LM would be the average rating for the four replicate specimens of between Light and Moderate.

Table 3. Mechanical property test results

Aspen/CFF /Resin (%)	Board structure	Density (g/cm^3)	MOE	MOR	Ratio IB	TS	WA
95/0/5	Single Layer	0.78	1.00	1.00	1.00	1.00	1.00
75/20/5	Single Layer	0.80	0.96	0.90	0.93	0.58	0.57
75/20/5	3 Layer CFF core	0.82	1.06	0.71	1.11	1.14	1.02
75/20/5	3 Layer CFF faces	0.76	0.73	0.95	1.31	1.30	1.12
47.5/47.5/5	Single Layer	0.78	0.73	0.82	1.36	0.38	0.48
0/95/5	Single Layer	0.74	0.49	0.61	0.98	0.27	0.36

In our evaluations, mould first formed on the bottom surfaces (closest to water) that were exposed to a slightly higher humidity. Within three weeks, some mould could be seen on the top, edge, and bottom surfaces of most specimens. Mould continued to grow as the specimens were monitored weekly for 10 weeks, but the magnitude in surface coverage by the mould seemed to peak at about 7-8 weeks. Although some differences in mould coverage seemed to exist, the variation in coverage resulting from our preliminary test methodology was too great to allow us to draw conclusive results. We believe this variation in mould coverage is as much or more related to laboratory set-up than to the genuine mould-resistive properties of the wood-CFF systems evaluated. We believe that we can improve upon the accuracy and precision of this test methodology in follow-up work.

Table 4. Decay test results and evaluation of surface mould potential

Aspen/CFF /Resin (%)	Board structure	Percent weight loss Brown Rot	White Rot	Mould Rating
95/0/5	Single Layer	65	47	M
75/20/5	Single Layer	34	32	MS
75/20/5	3 Layer CFF core	31	43	LM
75/20/5	3 Layer CFF faces	11	11	S
47.5/47.5/5	Single Layer	6	11	M
0/95/5	Single Layer	16	20	LM

These preliminary evaluations indicated that higher concentrations of CFF-fibre in MDF might provide some enhanced resistance to the initiation of mould on the surface of MDF (see Fig. 3). In Fig. 3, the top two specimens in each of the two left-side pans were 75/20/5 (Wood/CFF/Resin) with a 3 Layer distribution with CFF in the core (see Fig. 3 right), the middle two specimens were each 75/20/5 with a uniform distribution through the thickness, while the bottom two were 95/0/5 using wood fibre without CFF (see Fig. 3 left). Whereas, the top two specimens in the two right-side pans were each 0/95/5 using a uniform distribution of CFF through the thickness of the MDF, the middle two specimens were 47-5/4735 using a uniform distribution, while the bottom two were 75/20/5 with a 3 Layer with CFF just in the faces. In each two specimen set, the upper specimen exhibits the top (lower humidity) surface while the lower of the two is tipped over to exhibits the lower (higher humidity) surface exposed closer to water.

The mould was always more prevalent closer to, but not in direct contact with, the open water source on the bottom of the exposure pan (see Fig. 3). Also, because the PF resin may be preferentially binding to the free OH binding sites on the CFF and the wood fibre, and because these sites may also be the sites at which molds take hold and grow, the absence of those exposed sites could explain how and why mould could be inhibited. This work continues.

SUMMARY

We evaluated the properties of MDF prepared by using a series of chicken feather fibre-aspen wood fibre mixtures. Initial mechanical properties show some loss in strength and stiffness for feather fibre-wood fibre mixtures when compared to the properties of all-wood control panels, but optimisation of resin chemistry and processing procedures has yet to be studied. More importantly, the physical properties of feather fibre-wood fibre mixtures showed a marked improvement in resistance to water absorption and thickness swell over all wood fibre control panels, probably related to the hydrophobic component amino acids within the keratin in CFF. Further testing is currently being done to determine the threshold(s) of feather fibre required to decrease thickness swelling and increase water-resistance. We are also studying ways to refine the processes to optimise the strength properties of the wood-CFF panels and resin-fibre compatibility.

REFERENCES

1. G. Parkinson, "Chementator: A higher use for lowly chicken feathers?" Chem. Eng (1998), 105(3):21.
2. G. Gasser, W. F. Schmidt, M. J. Line, R. M. Waters, and C. G. Thomas. *Fiber and fiber products produced from feathers*. U. S. Patent No. 5,750,030. 1998.
3. ASTM D1037, Standard test methods for evaluating properties of wood-base fibre and particle panels materials. American Society for Testing and Materials. Book of Standards Vol 4.10 Wood. West Conshohocken, PA. USA.
4. ASTM D1413, Standard test method for wood preservative by laboratory soil-block cultures. American Society for Testing and Materials. Book of Standards Vol 4.10 Wood. West Conshohocken, PA. USA.
5. J. E. Winandy, J. H. Muehl, "Development of a test of mold potential for wood-based composite products (In-preparation).
6. M.Kunio, R. Arai, Y. Yakahashi, and A. Kiso, "*The primary structure of feather keratins from duek (Anas platyryhychos) and pigeon (Columba livia)*." Biochem. Biophys. Acta (1986) 836:6-12.

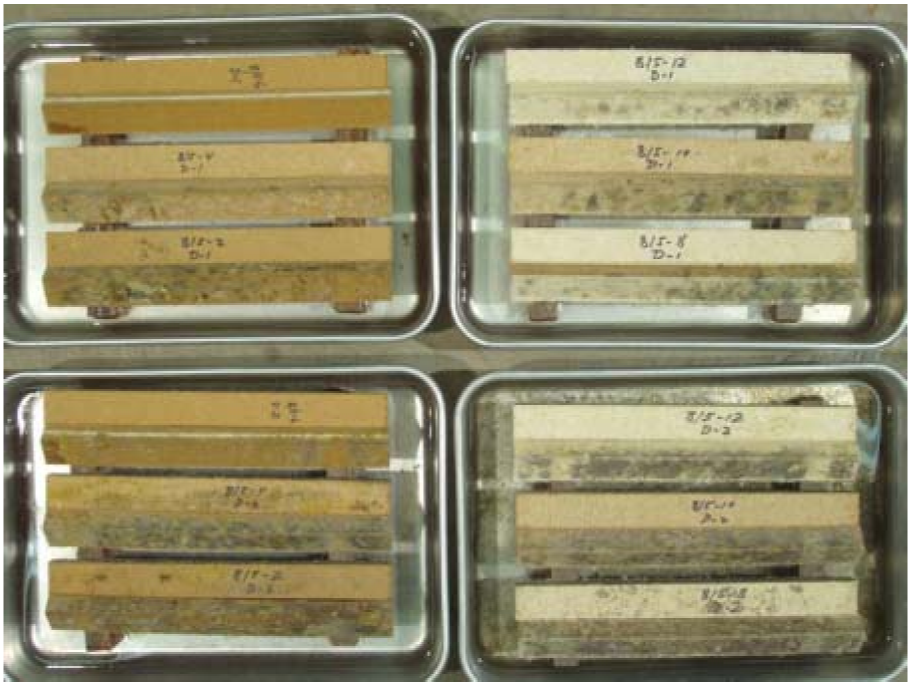

Fig. 3 evaluating potential for mould growth when woodfibre-rich (left) MDF is compared to CFF-rich MDF (right) after being exposed in a covered container and suspended above liquid water, but not in direct contact with that water [5].