Properties of Wood–Plastic Composites Manufactured from Wood Flour and Wood Pellets

Researchers at UMaine evaluating Maine residuals for manufacturing wood-plastic composite products.

Highlights

With global awareness in addressing environmental impacts and minimizing emissions, the wood composites industry is seeking more environmentally friendly materials for their products. With the utilization of recycled plastics and waste wood-based fillers, wood plastic composites (WPCs) manufacturing can be considered a green technology.

In North America, WPC manufacturers face supply chain challenges in cost effective delivery of their fiber materials, due to the low bulk density nature of wood flour. Reducing the shipped bulk density of wood fiber to WPC manufacturers offers reduced transportation costs with added benefits of in material handling and lower explosion risk.

This study is a continuation of earlier work found in *Properties of Wood Flour and Pellets Manufactured from Secondary Processing Mill Residues*, determining the physical and mechanical properties of polypropylene (PP)-based WPCs made from wood flour and wood pellets generated from mill residuals sourced in Maine.

A full technical article on this work can be found in the peer review journal article *Polymers* **2021**, *13*, 2769. https://doi.org/10.3390/polym13162769

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BACKGROUND

The purpose of this study was to reduce the delivered fiber cost to wood-plastic composite (WPC) manufacturers. The low density and higher volume of the wood flour make longer distance transportation disadvantageous in terms of cost. While the production cost of wood pellets is slightly higher than wood flour, a higher weight of pellets can be transported via truck trailer due to a bulk density roughly three and half times higher than wood flour.

This study explored the utilization of a compacted wood flour, i.e., wood pellets to manufacture WPCs and compare performance characteristics against WPCs manufactured using conventional wood flour. Then, the physical and mechanical properties of the resulting composite products were determined.

MATERIAL PREPARATION

Northern White Cedar (*Thuja occidentalis*), Eastern White Pine (*Pinus strobus*), Eastern Spruce-Balsam Fir (*Picea rubens-Abies balsamea*) and Red Maple (*Acer rubrum*) mill residues (planar shavings, sawdust, and small chips) were obtained from local sawmills in Maine. A Bliss Eliminator Hammermill with 0.5 mm screens was used to reduce the mill residues, then classified using a Gilson screen shaker at 20, 40, 60, 80, and 100 mesh sizes. The wood flour for each species collected at the 40-mesh screening (425-850 micron) was used as the feedstock for both wood pellet and control WPC sample production.

PRODUCTION

Pellet Manufacture

A Lawson Mills plate-type Pellet Mill (LM72A) was used for the production of wood pellets. For each species, pellets were manufactured using the 40-mesh size fraction, with the moisture content of the wood flour maintained between 10 and 15% to allow for optimal pellet formation.

WPC Manufacture

For each wood species, 40-mesh wood flour and wood pellets manufactured from the same flour were oven dried and used as the fiber source. The wood pellets were ground back to a powder using a Brabender knife grinder. Four formulations (Figure 1) for each wood species were manufactured using polypropylene (PP) sourced from ExxonMobil. In Formulations #3 and #4, maleic anhydride polypropylene (MAPP) from SI Group, Inc. was used as a compatibilizer. Each of the 16 formulations were compounded using a 20 mm Brabender twin-screw extruder. The compounded filaments were cooled, knife milled, then injection molded into standardized testing coupons using a Mini-Jector Model #55E injection molder.

Table 1: Raw material formulations of WPCs for each wood species.

Raw Materials	1st Formulation	2nd Formulation	3rd Formulation	4th Formulation
Wood flour	20%	0%	20%	0%
Ground wood pellets	0%	20%	0%	20%
PP	80%	80%	78%	78%
MAPP	0%	0%	2%	2%

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The University of Maine, founded in Orono in 1865, is the state's premier public university. It is among the most comprehensive higher education institutions in the Northeast and attracts students from across the U.S. and 65 countries. UMaine students directly participate in groundbreaking research working with world-class scholars. The University of Maine offers doctoral degrees in 35 fields, representing the humanities, sciences, engineering and education; master's degrees in nearly 70 disciplines; 90 undergraduate majors and academic programs; and one of the oldest and most prestigious honors programs in the U.S.

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CHARACTERIZATION

Particle Dispersion

WPC samples were prepared using a rotary microtome, and viewed using a Zeiss NVision 40 scanning electron microscope (SEM) to study particle disperion in the samples. Particle sizes were calculated and categorized using digital imagry. Through analysis, it was inferred that WPCs made from wood pellets had better particles' dispersion than WPCs made from the wood flour (Figure 1).

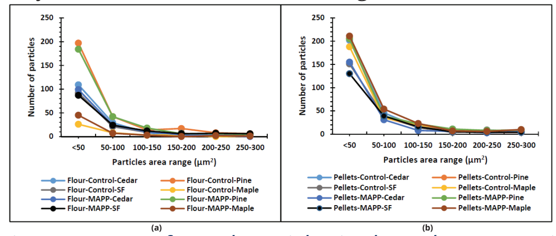

Figure 1: Area of wood particles in the polymer matrix (a) wood flour; (b) wood pellets

WPC Density

Density for the 16 WPC formulations was determined in accordance with ASTM D792. The average density of PP is 900 kg/m³. Figure 2 shows the density of WPC samples of wood flour and pellets in different formulations. For all sample formulations, the density observed was higher than 900 kg/m³. For all cases, WPCs made from wood pellets with MAPP showed a higher density. The increase in density of WPCs made with wood pellets is because of ground wood pellets being denser than the wood flour used.

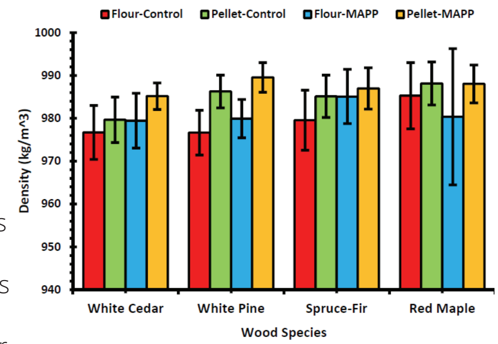

Figure 2: Density of WPC Formulations

Tensile, Flexure and Impact

Tensile coupons were evaluated in accordance with ASTM D638. WPCs manufactured using pellets or flour had no significant difference in the tensile values of the composite products (Figure 3a;3b). Flexural bending was performed in accordance with ASTM D790. Figure 4a and 4b shows the wood filler (wood flour or pellets) did not influence the flexural strength or stiffness. Izod impact resistance was determined in accordance with ASTM

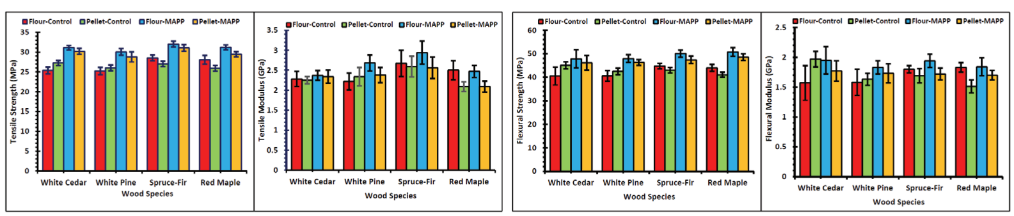

Figure 3: Tensile Strength (a); Stiffness (b), Flexural Strength (a); Stiffness (b)

D256. As seen in both the tensile and flexural testing, the impact strength (Figure 4) was not influenced statistically by the filler type (wood flour versus wood pellet).

CONCLUSIONS

- The physical and mechanical properties of WPCs made from either the wood flour or wood pellets were similar.
- Feedstock distribution was similar for both wood flour and pellet formulated WPCs.
- Dispersion was greater for WPCs with pellets than with wood flour.
- MAPP improved the physical and mechanical properties of WPCs for each wood feedstock and wood species.
- On average, WPC samples of spruce-fir species possessed the best properties.

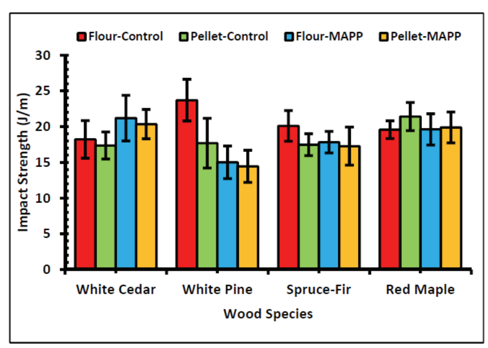

Figure 4: Impact Strength of WPCs

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