Properties of Wood Flour and Pellets Manufactured from Secondary Processing Mill Residues

UMaine processing and characterizing Maine-sourced wood residuals for use in wood flour and pellet production.

Highlights

Wood-plastic composites (WPCs) have seen increased use in outdoor construction applications. In recent years, there has been advancements in the commercialization of lower carbon footprint products generated through additive manufacturing (AM). With both of these products, one of the primary components is natural fiber, typically wood flour.

One of the greatest costs in wood flour supply is transportation. Shipping costs often exceed the material costs due to the material's low bulk density, increasing the delivered raw material costs to WPC and AM manufacturers and the price of finished products. Reducing the delivered cost of wood fiber, either through local production or using pre-densified flour in pellets, reduces overall production costs and increases competitiveness in the market.

This study focused on the processing and characterization of mill residues into wood flour and pellets from four wood species in Maine to serve as feedstock for use in the manufacture of WPCs and in additive manufacturing.

A full technical article on this work can be found in the peer review journal article *Polymers* **2021**, *13*, 2487. https://doi.org/10.3390/polym13152487

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BACKGROUND

This research focused on the collection, processing and characterization of four Maine-sourced mill residual wood species for use as feedstock in manufacturing wood-plastic composites (WPCs) and in additive manufacturing (AM). Maine currently has no wood flour manufacturers, with current and emerging manufacturers of both WPCs and fiber-filled AM products relying on imported wood flour or pre-compounded materials. The purpose of this research was to establish initial baseline information on available wood residuals, characterization of wood flour generated, and pellets manufactured from the flour as a viable feedstock for use in WPCs and fiber-filled AM products to increase utilization and diversify markets for Maine's wood residuals.

SAMPLING, WOOD FLOUR AND PELLET PRODUCTION

Approximately 100-150 kg of 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 (Figure 1, with a 3 cm scale bar for reference).The residues as received were dry (either air or kiln) and free of bark or other contaminates.

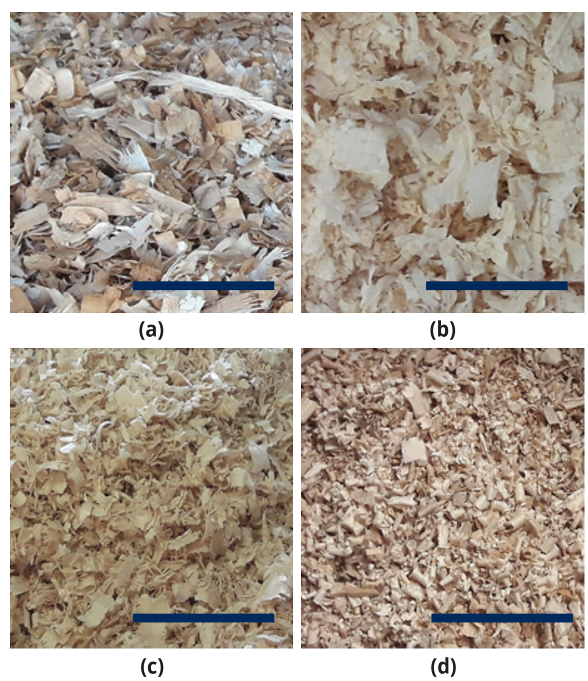

Figure 1: Mill residues of (a) White Cedar (b) White Pine (c) Spruce-Fir (d) Red Maple

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.

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

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ABOUT UMAINE

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

The moisture content of the mill residues, hammer mill grindings, screened wood flour, and wood pellets was determined for each species (Figure 2a) in accordance with American Society of Testing and Materials (ASTM) Standard D4442–20. Bulk density for the same materials (Figure 2b) were determined in accordance with ASTM E873–82.

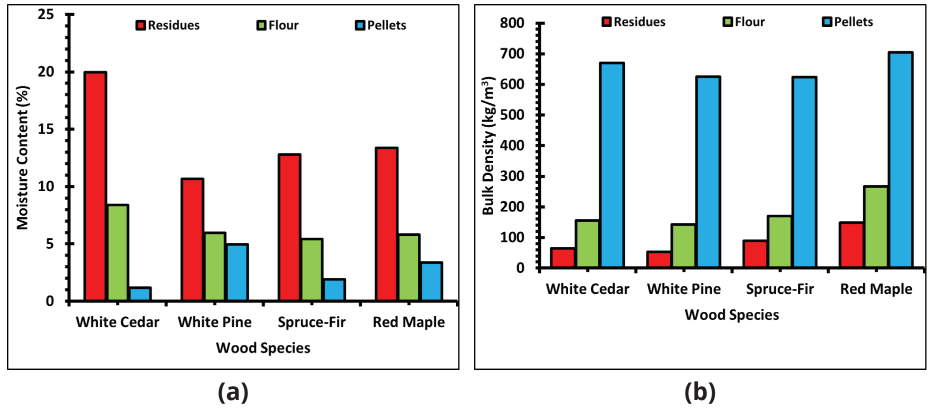

Figure 2: Plots of (a) change in moisture content with wood processing steps, and (b) change in bulk density with different wood processing steps.

Wood Flour

Particle size geometry of the processed wood flour was determined in accordance with the American National Standards Institute/American Society of Agricultural Engineers (ASAE) S319.4. Particle aspect ratios (Figure 3) of the various mesh sizes was determined using digital optical analysis. The morphology of the wood flour was observed for each species studied and by mesh size fraction using Zeiss NVision 40 Scanning Electron Microscope (SEM).

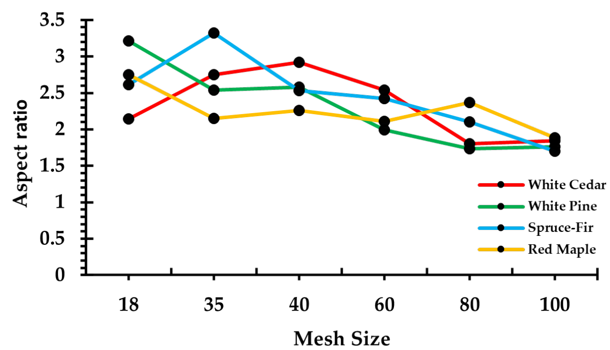

Figure 3: Relation of aspect ratio with different mesh sizes

Wood Pellets

Pellet dimensions were determined using a vernier caliper. Pellet durability was determined in accordance with ASAE S269. Ash content was determined using a thermo-gravimetric analyzer (TGA).

Table 1: Various properties of wood pellets from unsieved and 40-mesh flour.

Wood Species	Moisture Content (%)	Bulk Density (kg/m³)	Ash (gm)	Avg. Diameter (inches)	Avg. Length (inches)	Avg. Range of Length (inches)	Durability (%)
White Cedar (unsieved)	1.19	670	0.53	0.24	0.40	0.16–0.67	95
White Cedar (40 mesh)	2.67	699	0.45	0.24	0.40	0.14–0.73	97
White Pine (unsieved)	4.94	625	0.18	0.24	0.35	0.12–0.60	93.8
White Pine (40 mesh)	4.12	634	0.19	0.24	0.40	0.14–0.73	97
Spruce-Fir (unsieved)	1.91	624	0.32	0.24	0.48	0.19–0.93	75.8
Spruce-Fir (40 mesh)	2.57	671	0.28	0.23	0.46	0.17–0.84	82.5
Red Maple (unsieved)	3.39	705	0.41	0.24	0.49	0.17–0.93	67.2
Red Maple (40 mesh)	0.12	738	0.44	0.23	0.48	0.17–0.95	83.8

CONCLUSIONS

- On average, the moisture content of the mill residues reduced by 54% via hammermill and 76% by pelletization.
- Residual bulk density increased (on average) by 119% via hammermill and 747% by pelletization.
- Pellets formed using 40 mesh sieved flour typically exhibited a higher range of length variability, but a higher durability rating and higher buk density versus unsieved wood flour.

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