19th International Conference on Environmental Science and Technology

Kos, Greece, 3 to 6 September 2025

Properties of Thermo-Mechanically and Steam-Treated Recycled Wood Fibers from Post-Consumer Waste and Processing Residues

Xu C.[1,*], Alao P.[1], Adamopoulos S.[1]

[1] Department of Forest Biomaterials and Technology, Swedish University of Agricultural Sciences, Uppsala, Sweden

*corresponding author: Changling Xu
e-mail: changling.xu@slu.se

Abstract Engineered wood products like medium-density fiberboard (MDF) are widely used in furniture and construction due to their low cost and ease of processing, with production steadily increasing along with the waste. This research investigates the characteristics of recycled fibers and compares them to virgin fiber; evaluation includes the fiber size distribution, water behavior, pH, buffer capacity, nitrogen content, as well as residual resin. Virgin fibers were produced via thermo-mechanical pulping (TMP). The process was modified (mTMP) to generate secondary fibers from fiberboard processing residues and post-consumer waste, including fiberboard and solid wood. The results thus confirmed the fiber shortening, increased fine content, and the possible presence of residual resin.
Keywords: Characterization; Fiber length; pH buffering; Post-consumer fiberboard; MDF

1. Introduction

Growing environmental regulations and increasing volumes of waste wood products are creating the need to develop economically viable recycling strategies for them, such as medium-density fiberboard (MDF). This includes recycling and reusing wood materials to maximize material efficiency in line with the cascading use of resources, thereby reducing the demand for virgin wood (Besserer et al., 2021). Currently, commercially viable recycling of diverse wood waste is lacking due to complex processing and degraded fiber quality (reduced size, presence of contaminants) (Hagel et al., 2021; Zimmer & Bachmann, 2023). Thus, comprehensive analysis is crucial to determine their suitability for fiberboard, guide process optimization, and define manufacturing parameters.

This study, within the framework of the EU-funded EcoReFibre project, evaluates the characteristics of recycled fibers by modified thermo-mechanical pulping (mTMP) and steam treatment (ST). The recycled fibers originate from post-consumer waste, including fiberboard (PF) and solid wood waste (SWW), as well as from fiberboard processing residues (FPR). These fibers were broadly characterized for MDF application, including fiber size, dynamic vapor sorption, pH and buffer capacity, nitrogen content, and residual resin. All these properties, especially fiber length, influence MDF performance.

2. Materials and Methods

Table 1 presents the fiber samples, including virgin fibers produced using the TMP process. mTMP produces a mix of virgin and recycled fibers (15% and 25%), while ST yields 100% recycled fiber. Although mTMP can also generate 100% recycled fiber from solid wood waste, direct process comparison is currently limited by ongoing optimization for specific wood waste streams (mTMP: solid wood; ST: fiberboard).

Table 1. Description of measured fibers

s/n	Samples	Description
1.	TMP virgin fiber	Reference
	mTMP fibers	Recycled mix: 85%,15% and 0% virgin
2.	R-15%	15% FPR
3.	R-25%	25% FPR
4.	SW-15%	15% post-consumer SWW
5.	SW-25%	25% post-consumer SWW
6.	W-25%	25% PF
7.	SW-100%	100% post-consumer SWW
	ST	Steam treatment recycled
8.	DR-100%	100% FPR
9.	DW-100%	100% PF

Fiber length was analyzed in the dynamic image analysis system QICPIC (Bütün Buschalsky et al., 2024). DVS analysis was performed on the wood dust using a DVS-ET-VID. Initial pH and buffer capacity were measured using a pH meter (METRIA, M21) by titration method (0.05 N NaOH / HCl). An organic elemental analyzer (Elementar

Vario EL with TCD detector) measured nitrogen content. Residual resin was studied using Fourier transform infrared (FTIR) spectroscopy (PerKinElmer UATR Two).

3. Results and Discussion

3.1. Fiber size distribution

Figures 1a (relative proportion) and 1b (cumulative percentiles) show fiber length distributions. Consistent with Savov et al. (2023), 100% recycled fibers were ~30% shorter with a flatter distribution and more bundled (> 4000 µm) fibers compared to the right-skewed shape of other samples (Figure 1a). Figure 1b reveals the smallest median length (X_{50}) for 100% recycled fibers, indicating finer fibers. 15% and 25% recycled fiber substitution maintained virgin fiber length distribution.

3.2. Dynamic vapour sorption

Fiber mixtures exhibited comparable water sorption (8.7% at 20 °C, 60% RH) to the reference. SW-100% showed the highest water sorption, while DR-100% and DW-100% absorbed the least. Furthermore, the ST-treated samples displayed a significantly lower water retention value (32.6% at 20 °C, 60% RH) relative to other batches.

3.3. Chemical properties

SWW fibers had comparable nitrogen content to virgin fibers (0.1%). Fibers from post-consumer fiberboard and processing residues showed 5-7 times higher nitrogen content at 25% substitution, likely due to residual resin as detected by FTIR (primary amide group at 1657 cm^{-1}), consistent with a previous report (Lubis et al., 2018). Incorporating recycled fibers increased initial pH compared to virgin fiber (pH 4.1). SW-100% displayed the lowest buffering capacity, while ST-treated samples (DR-100%, DW-100%) exhibited 63% higher buffering capacity than virgin fiber, primarily due to their high base capacity potentially linked to the elevated nitrogen content.

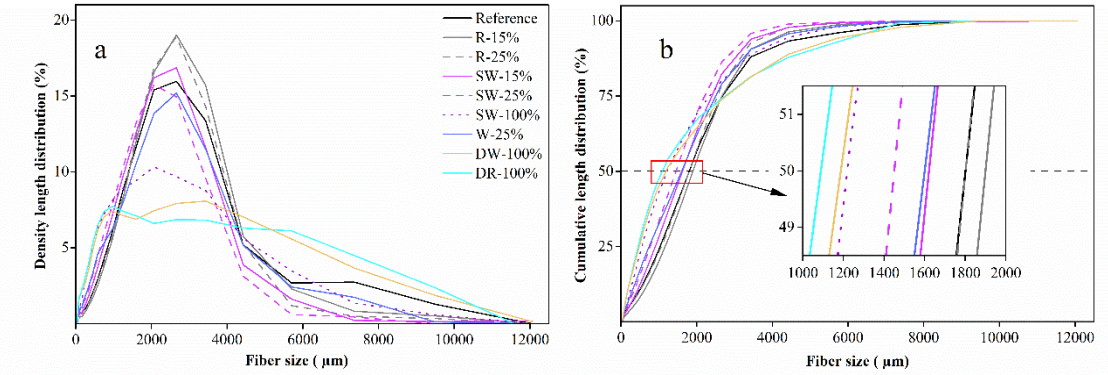

Figure 1. Density (a) and cumulative (b) distribution of fiber length by QICPIC.

4. Conclusion

This study confirms typical recycled fiber issues (increased dust, fiber shortening, chemical differences). While 15% and 25% recycled fiber sources showed similar size distributions, water sorption, and pH values, their nitrogen content varied significantly. These findings suggest the feasibility of using 15% or 25% recycled fibers for sustainable, cost-effective fiberboard, warranting future MDF performance and industrial potential assessment.

Acknowledgments

This research was funded by the Horizon project EcoReFibre (project No. 101057473, 2022-2026).

References

Besserer, A., Troilo, S., Girods, P., Rogaume, Y., & Brosse, N. (2021). Cascading recycling of wood waste: A review. Polymers, **13**(11), 1752.

Bütün Buschalsky, F. Y., Imken, A. A. P., Adamopoulos, S., Ahmed, S. A., Plinke, B., & Mai, C. (2024). Geometric changes of TMP fibres due to thermo-hydrolytic disintegration of waste MDF evaluated by three fibre analysers. Wood Material Science & Engineering, 1-9.

Hagel, S., Joy, J., Cicala, G., & Saake, B. (2021). Recycling of waste MDF by steam refining: evaluation of fiber and paper strength properties. Waste and biomass valorization, 1-13.

Lubis, M. A. R., Hong, M.-K., Park, B.-D., & Lee, S.-M. (2018). Effects of recycled fiber content on the properties of medium density fiberboard. European Journal of Wood and Wood Products, **76**, 1515-1526.

Savov, V., Antov, P., Panchev, C., Lubis, M. A. R., Lee, S. H., Taghiyari, H. R., Todorova, M., & Petrin, S. (2023). Effect of Hydrolysis Regime on the Properties of Fibers Obtained from Recycling Medium-Density Fiberboards. Fibers, **11**(7), 64.

Zimmer, A., & Bachmann, S. A. L. (2023). Challenges for recycling medium-density fiberboard (MDF). Results in Engineering, **19**, 101277.