Effects of Different Milling Processes on Properties of Douglas-fir Forest Residuals

Bon-Jae Gu[a], Girish Ganjyal[a], Jinwu Wang[b] and Michael Wolcott[b]

[a] Food Science, Washington State University [b] Composite Materials and Engineering Center, Washington State University

Introduction

Lignocellulosic biomass is composed of cellulose, hemicellulose and lignin. In order to gain higher digestible cellulose for enzymatic hydrolysis, lignin and hemicellulose which are interconnected with cellulose have to be detached from cellulose for better enzyme accessibility. Ball milling is one of the common means to reduce biomass crystallinity as well as particle size to increase surface area. These factors help boost enzyme contact for bioconversion, degrading cellulose to sugar. This results in a decreased degree of polymerization and hydrolysis time, while increasing the recovery of sugar from lignocellulosic biomass.

Objective

Operation costs of milling processes for biofuel from lignocellulosic biomass demands high specific energy consumption costs due to the grinding process. This process breaks down biomass into fine particle sizes, leading to high digestible lignocellulosic resources. Therefore, the objective in this study is to develop a milling process with low energy consumption while decreasing particle size and crystallinity of Douglas-fir Forest Residuals.

Milling Strategies

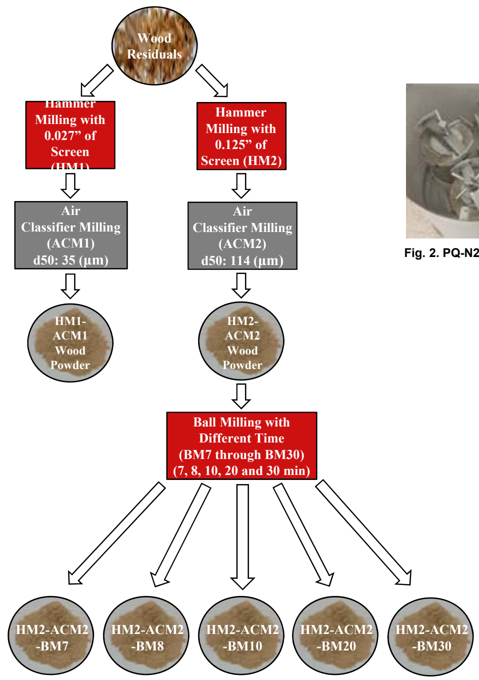

Fig. 1. Process diagram for wood powder.

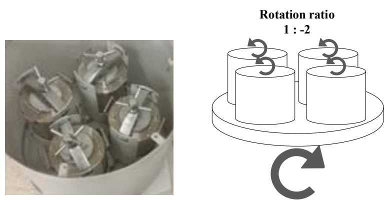

Fig. 2. PQ-N20 ball mill (left) and direction of rotation of ball milling (right).

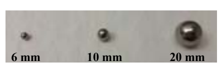

Fig. 3. Ball sizes used in milling process.

Table 1. Amount and weight of balls.

Diameter of ball	Number of balls	Total weight (g)
6 mm	4501 / jar	4161
10 mm	1011 / jar	4131
20 mm	15 / jar	502

Total Energy Consumption

Table 2. Energy consumption of each process (kWh/kg).

	Hammer Mill	Air Classifier Mill	Ball Mill	Total Energy Input
HM1-ACM1	0.23	2.31	-	2.54
HM2-ACM2	0.07	0.50	-	0.57
HM2-ACM2-BM7	0.07	0.50	0.47	1.04
HM2-ACM2-BM8	0.07	0.50	0.54	1.11
HM2-ACM2-BM10	0.07	0.50	0.68	1.25
HM2-ACM2-BM20	0.07	0.50	1.37	1.94
HM2-ACM2-BM30	0.07	0.50	2.04	2.61

Scanning Electron Microscope (SEM)

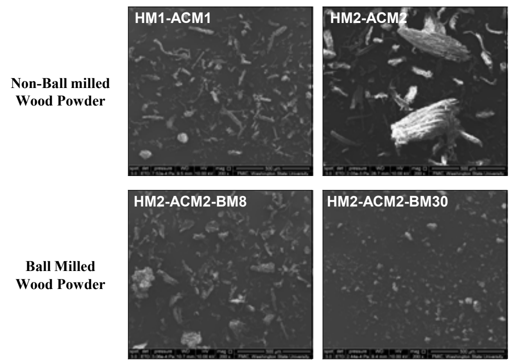

Fig. 4. Scanning electron microscope photos of non-ball milled and ball milled wood particles.

Median Particle Size and Energy Consumption

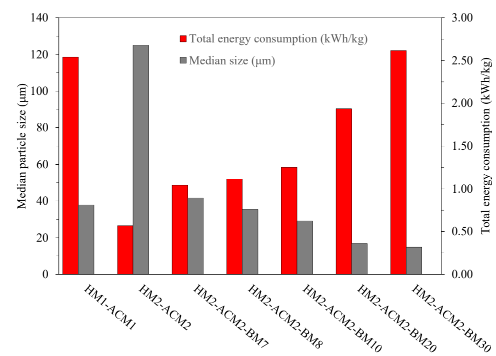

Fig. 5. Relationship between energy consumption and median size for different milling processes.

X-ray Diffraction Analysis (XRD)

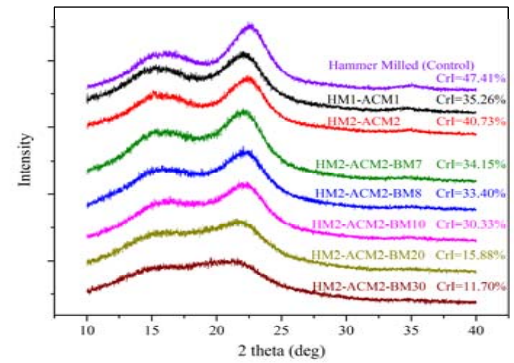

Fig. 6. Effect of milling processes and ball milling time on x-ray diffraction of wood residuals.

Effect of Milling Strategies

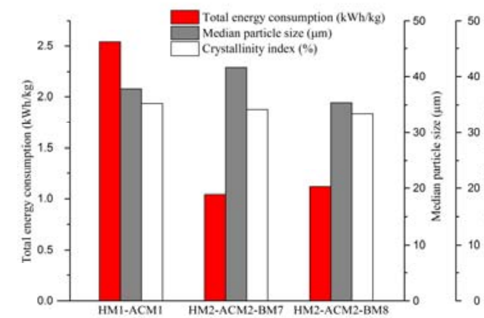

Fig. 7. Effect of different milling strategies on total energy consumption, median particle size, and crystallinity index.

Conclusion

- HM2-ACM2-BM8 wood powder showed lower energy consumption compared to that of HM1-ACM1, even though HM2-ACM2-BM8 has a smaller particle size (35.4 μm) than that of HM1-ACM1 (37.8 μm).
- HM2-ACM2-BM20 wood powder showed lower crystallinity (CrI=15.88%) than HM1-ACM1 (CrI=35.26%) although HM2-ACM2-BM20 consumed 1.94 kWh/kg, which is higher energy than HM1-ACM1 (2.54 kWh/kg).
- SEM images showed changes in wood particle size with different milling processes.

NARA
Northwest Advanced Renewables Alliance

NARA is led by Washington State University and supported by the Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30416 from the USDA National Institute of Food and Agriculture.