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Torrefaction of pulp industry sludge: Experimental validation, opportunities and challenges

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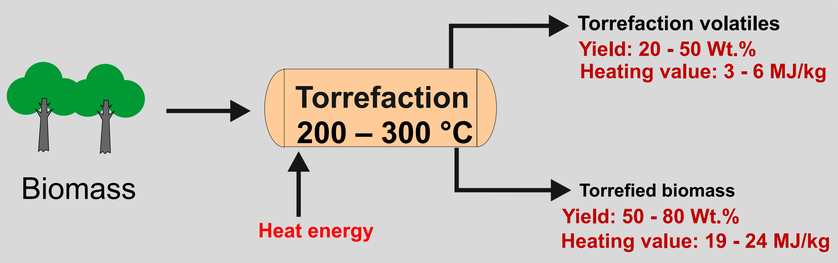
Objective: To study the influence of torrefaction treatment on the fuel characteristics and composition of pulp industry sludge.

Introduction

What is torrefaction?



Torrefaction is a thermal pretreatment process which is aimed at improving the fuel characteristics of the biomass. Generally, carried out in the temperature range of 200 - 300 °C in the inert environment[1].

What is pulp industry sludge?

Generally, there are three different type of sludge produced in a pulp mill[2].

Primary sludge
Produced during primary treatment of pulp mill wastewater in sedimentation basin or clarifier.

Secondary sludge
Generated during the biological treatment of the wastewater from the primary treatment.

Tertiary sludge
Generated when the effluent from biological treatment is further treated with chemical flocculants.

What are the challeges with torrefaction and pulp sludge?

Torrefaction: The economic feasibility of torrefied pellets are not yet competitive to the coal because of the increasing price of woody biomass. Thus, there is a need to produce pellets from low cost feedstock in order to improve the process economics.

Pulp sludge: Today, pulp industry sludge is being handled through landfill, combustion, anaerobic digestion, and in agricultural activities. Because of the legislation, land application is prohibited. Because of the high water content combustion may not be a feasible option. Thus, there is a need to find alternative solutions to handle pulp sludge in order to improve the sustainability of the pulp mills.

Our approach

Mechanically dewatered pulp sludge can be used as a low-cost/no-cost raw material to produce torrefied pellets.

Materials and Methods

Materials

- Dewatered pulp sludge from aspen wood pulping through chemical-thermo-mechanical pulping.
- Mixture of primary and secondary sludge.

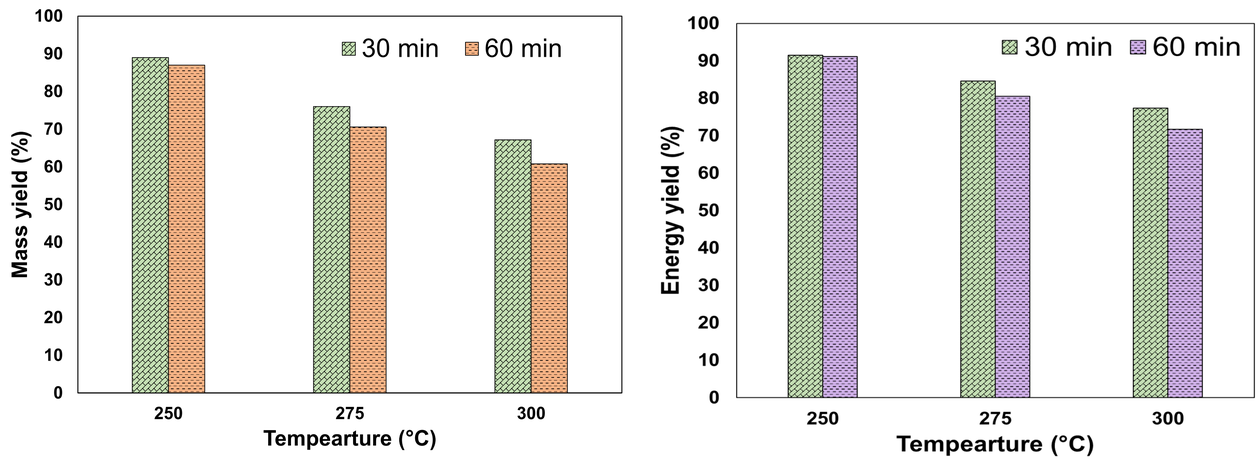
Methods

- Torrefaction (Continuous reactor at 1 kg/h, 250, 275, 300 °C)
- Heating value (EVS-EN ISO 18125:2017)
- Proximate and ultimate analysis (EVS-EN ISO 16948:2015)
- Fiber analysis (ANKOM 2000, ANKOM Technology, USA)
- Ash composition (EVS-EN ISO-16967)
- Ash melting temperatures (CEN/TS 15370-1:2006)
- Slagging and fouling (theoretical indices)

Fig 1. Continuous torrefaction reactor

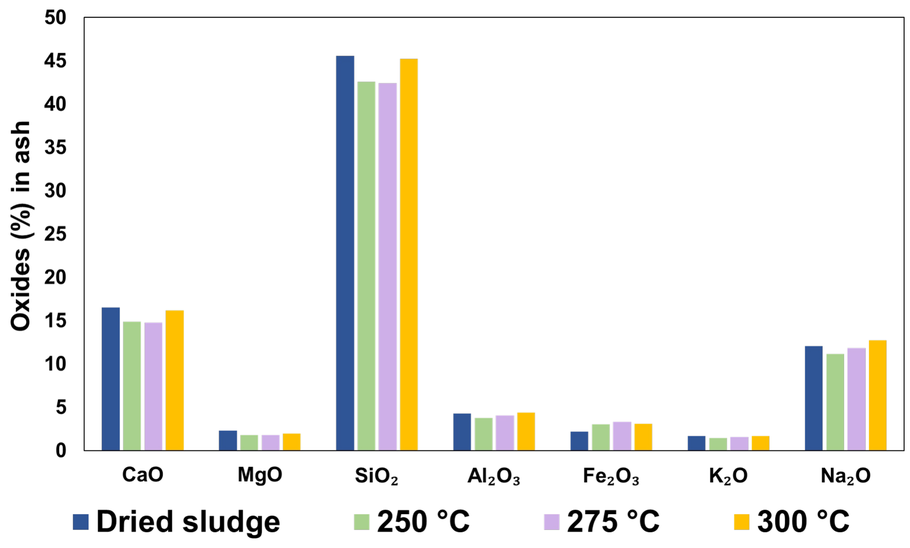
Results

Fig 2. Mass and Energy yield



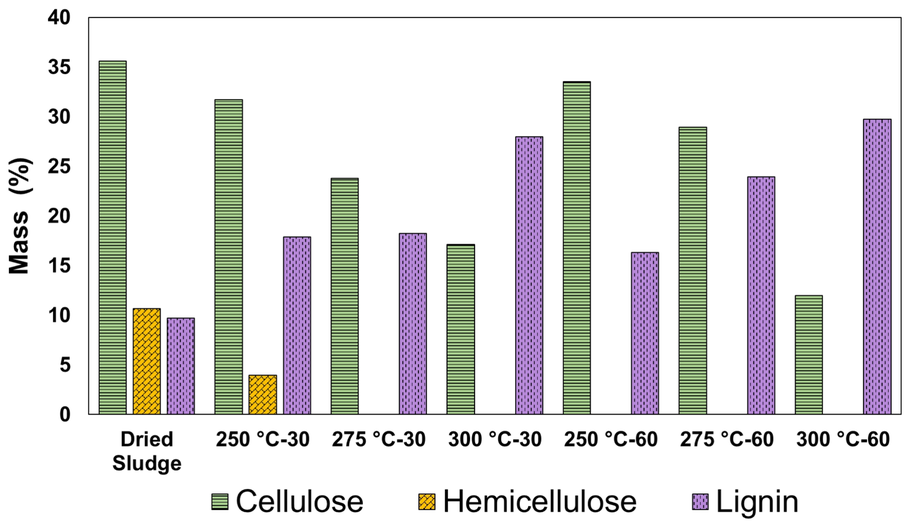
Mass and Energy yield was in the range of 89 - 61 wt.% and 91 to 71% respectively for the torrefaction temperature of 250 - 300 °C.

Fig 3. Ash composition of dried and torrefied pulp sludge



The ash content increased from 12 wt.% for dried sludge to 21 wt.% at 300 °C. The ash mainly contained SiO_2, CaO and Na_2O.

Fig 4. Chemical composition of dried and torrefied pulp sludge in terms of biomass fibers



Dried sludge contained 35, 10, 9 wt.% of cellulose, hemicellulose and lignin respectively. At 300 °C, cellulose content reduced by 65% and lignin content increased by 220 %

Table 1: Ash fusion indexes of dried and torrefied pulp industry sludge

	Ash Fusion Indexes				
	Dried sludge	250-60	275-60	300-60	Slagging and fouling degree
Base/acid ratio	0.70	0.70	0.72	0.72	Medium
Slag viscosity index	68.44	68.44	68.08	68.05	Medium
Silica content (%)	45.59	42.56	42.42	45.24	High
Fouling index	12.12	14.89	18.19	23.10	Medium
Bed agglomeration index	0.16	0.24	0.25	0.21	high when BAI <0.15

Although pulp sludge contained high amount of SiO_2, the theoretical ash slagging fouling indices are in the medium range. The reason could be the lower amount of Cl, P and K.

Conclusion

Torrefaction treatment improved the fuel characteristics of the pulp sludge to a level of competing with low rank coal such as lignite. However, the increased ash content and low ash melting temperatures are the challenges. Pulp sludge could be a feasible organic resource compared with agricultural wastes in terms of ash related issues because of lower amount Cl, P and K.

Opportunities

- Availability of pulp industry sludge at large quantities and at low or no-cost
- Can be easily integrated with pulp mills
- New income source for pulp mills
- Torrefied pellets can be produced at competitive price

Challenges

- High moisture content
- High ash content
- Low ash melting temperatures

References

1) Doddapaneni TRKC, Praveenkumar R, Tolvanen H, Rintala J, Konttinen J. Techno-economic evaluation of integrating torrefaction with anaerobic digestion. Appl Energy 2018;213:272–84. https://doi.org/10.1016/j.apenergy.2018.01.045.
2) Bajpai P. Generation of Waste in Pulp and Paper Mills. In: Bajpai P, editor. Manag. Pulp Pap. Mill Waste, Cham: Springer International Publishing; 2015, p. 9–17. https://doi.org/10.1007/978-3-319-11788-1_2.

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