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Realizing Sustainable Biomass Utilization Through Circular Economy Concepts

Owing to carbon neutrality, biomass is a popular renewable energy source in the global context. In Sri Lanka, a significant portion of primary energy supply in industrial and domestic sectors comes from biomass sources but a sustainable biomass supply chain is yet to be realized. Researchers at the Department of Chemical and Process Engineering are working towards the realization of circular bioeconomy with novel concepts of thermochemical biomass pretreatment technologies.

Flue gas driven torrefaction for a sustainable biomass supply chain

Torrefaction is a thermochemical pretreatment method to increase the energy density of biomass which became a hot topic in the bioenergy research community in the recent past. The process is carried out at 200-300 C for about one-hour in an inert atmosphere. However, large-scale use of inert gas is neither realistic nor economical, and alternative methods are being investigated by researchers all over the world. The waste heat available in the industrial flue gas at a similar temperature range is best suited as a torrefaction medium. Those industries have a good opportunity to recover the waste heat through the integrated torrefaction process. However, the flue gas generally contains 2-6% oxygen which provides a slightly oxidative atmosphere instead of the inert atmosphere expected in the torrefaction process.

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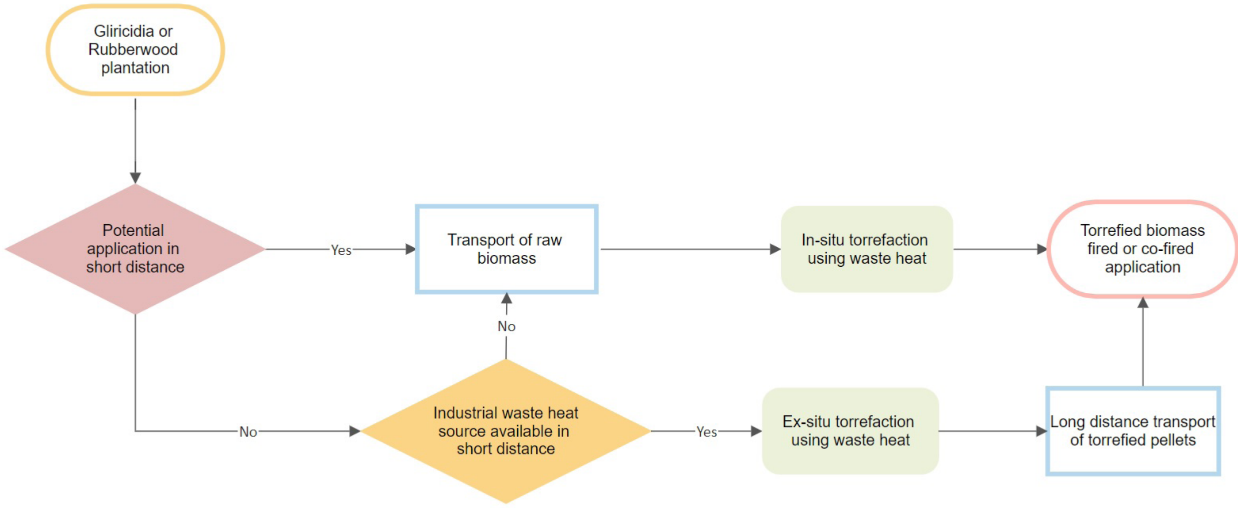

Figure 1 : In-situ and ex-situ torrefaction concepts for woody biomass

> Sri Lanka being an agricultural country, a considerable amount of rice straw and rice husk is annually produced and mostly underutilized.

At the Department of Chemical and Process Engineering, we are investigating the effect of oxidative torrefaction for common woody biomass sources available in Sri Lanka, namely Gliricidia and Rubberwood. It is desirable to achieve high energy yield along with less mass yield for the improved energy density of biomass. Therefore, the effect of torrefaction temperature, residence time, and oxygen content in the torrefaction medium is being investigated in a lab-scale torrefaction reactor and the optimization based on energy-mass co-benefit is being carried out. With successful implementation, industries with flue-gas waste heat can be benefitted by producing torrefied wood pellets as a value-added product. On the other hand, industries with biomass-fueled dryers, heaters, boilers, and furnaces can also be benefitted by replacing raw biomass with torrefied biomass due to improved combustion process and reduced logistic costs. Improved energy density results in reduced transportation cost and improved hydrophobicity makes open-air storage feasible. Further, torrefaction makes preprocessing easy and less energy-intensive due to improved grindability.

The concepts of in-situ and ex-situ torrefaction are demonstrated in Figure 1. If the potential application is within a short distance, transportation of raw biomass and in-situ torrefaction at the application site would be feasible. Else, ex-situ torrefaction at a waste heat source available in a short distance would be beneficial. In either case, the circular bioeconomy concept is realized due to the use of waste heat in the flue gas.

Combined pretreatment of agricultural waste for better ash chemistry and energy density

Sri Lanka being an agricultural country, a considerable amount of rice straw and rice husk is annually produced and mostly underutilized. This is mainly due to high ash content and low energy density that hinder the effective utilization of those in combustion applications. Even though, torrefaction increase the energy density of agricultural waste, a challenge remains because of the large

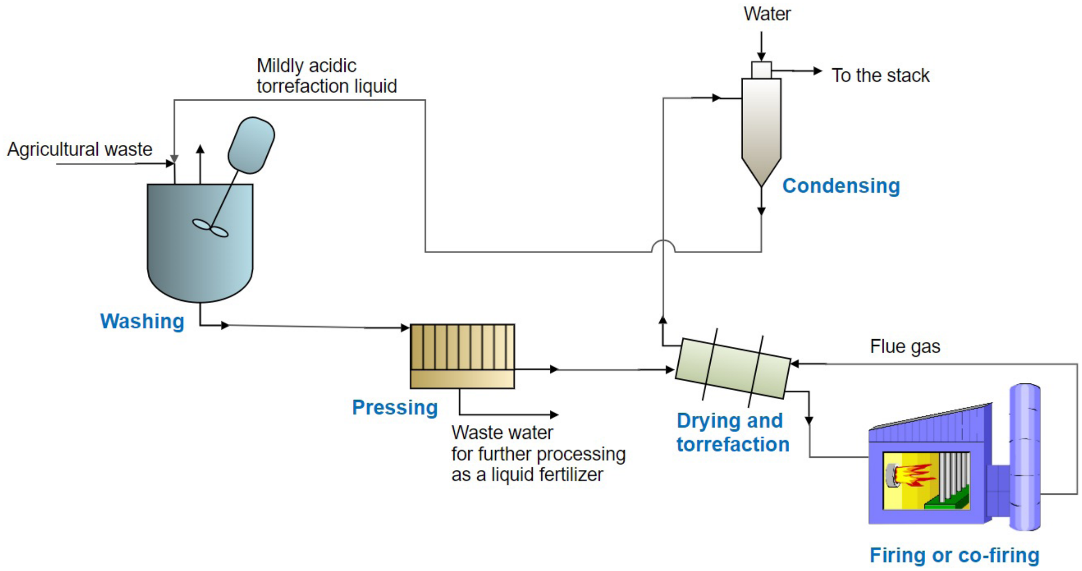

Figure 2 : Combined pretreatment concept for agricultural waste

amount of inorganic minerals remaining in the torrefied product. It is well-known that alkali metals in biomass have significant impacts on subsequent applications. Mainly alkali vapors react with silica to form alkali silicates causing major sintering and fouling problems. The presence of chlorine results in the formation of alkali chlorides which are highly corrosive and melting on superheater metal surfaces is problematic. In addition, alkali chlorides remain in flue gases may form particles making fly ash more corrosive. Water washing is an effective pretreatment method to remove such troublesome elements from biomass. After years of research on washing and torrefaction as separate pretreatment options, nowadays the focus is on combined pretreatment of washing and torrefaction considering the positive effect of both pretreatment methods. This process plays a vital role in the pretreatment of agricultural waste such as rice straw and rice husk.

The liquid byproduct produced during torrefaction mainly contains water and organic acids (mainly acetic acid and formic acid) and dilute acid washing using this torrefaction liquid product is considered to be an effective pretreatment technology. Further, mineral-laden wastewater can be a source of liquid fertilizer with necessary upgrading. Figure 2 represents the concept of such combined pretreatment technology considering industrial installation.

At the Department of Chemical and Process Engineering, we are working on optimization of combined washing and torrefaction pretreatment parameters including pre-washing and post-washing options for ultimate application of agricultural waste as combustion or cofiring feedstock. The optimization is based on energy densification, fouling, slagging and corrosion propensities, and combustion reactivities.

Findings of the studies done so far reveal that pretreatment technology is of utmost importance for making biomass a sustainable resource. Circular economy concepts can add extra value to the sustainability of the bioenergy sector while making the pretreatment process more economical and could play a major role in making local industries more resilient towards fuel switching which is inevitable sooner or later.

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