Hot Water Washing of Rice Husk for Ash Removal

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ABSTRACT

The improvement of combustion quality of rice husk can be achieved by water washing as pre-treatment. Particle size and temperature are important parameters to consider when washing biomass. Conductivity of the washing water was measured to identify the leaching behaviour of ash constituents. Up to 25.2% of ash removal was observed at 75^0C with 1-1.4mm particle size sample. Compositions of ash constituents were determined to calculate fouling tendency index. Results shows a significant reduction of ash constituents; Fe, K, Al, Ti and P as water temperature increases. In contrast Ca, Mg and Na got increased by water washing.

KEYWORDS: Rice Husk; Ash Removal; Hot Water Washing

INTRODUCTION

Biomass is a carbon neutral, renewable energy source which has been used for decades. Recently, usage of agricultural wastes and wood biomass as fuel sources for boilers, furnaces have increased significantly. But studies done on the agricultural wastes as energy sources are not adequate to develop new systems and address the technical problems arise in Sri Lankan context. Since rice husk is abundant in Sri Lanka which do not utilize effectively, removal of ash in rice husk is experimented in this study.

Ash is an inorganic substance present in fuels containing alkali metals, Alkali earth metals, silicates, chlorides and sulfates. In Rice Husk the ash content is high as 20.3%(w/w) (Gudka at al.,2016). Deposition of these ash constituents in boilers and furnaces during combustion of biomass creates operational issues such as slagging, fouling and corrosion. Many studies have experimented washing techniques as ash removal pre-treatment method for different types of biomass. These studies have tested the effect of parameters such as temperature, particle size and washing time as in individual basis (Deng et al., 2013), but the interrelationship between those parameters have not studied yet. Through this study, the effect of temperature and particle size with ash removal percentage for rice husk will be evaluated. This allows to determine the optimum operation conditions that can be used in the industry in order to remove ash from rice husk before combustion.

METHODOLOGY

Rice husk was obtained as it was not encountered any rain washing and sieved into three size ranges; 1-1.4, 1.4-2.8, 2.8-5.6 mm. A total of twelve samples were prepared according to temperatures of 40, 50, 65, and 75°C for each particle size range. 10g of rice husk

sample was washed in 800ml of water. High water to biomass ratio was maintained to minimize the effect of water/biomass ratio on test results. The optimization of water consumption will be done in future research. Washing treatment was conducted with tap water obtained from public water supply having conductivity around 200µS/cm. Washing in elevated temperatures were done using a water bath with automatic temperature control. The beaker with the water was kept inside the water bath until it reaches the expected temperature. After the water in the beaker attained the required temperature biomass was introduced by directly soaking in the water.

Prepared samples were washed for two hours. Conductivity of the washing water was measured in every five minutes and recorded to identify the ash removal from the rice husk. Before adding the sample, conductivity of the water was recorded to compensate the conductivity increase of water due to temperature.

After washing, the biomass was strained and air dried for one day. Then to remove moisture, air dried rice husk samples were first oven dried for 3 hours at 105^0C prior to determine the ash quantity. Determination of ash quantity in washed rice husk samples was carried out according to standard test method of ASTM E1755-0 (2015). The ash composition Fe, Ca, Mg, Na, K, Al, Ti and P of raw and washed rice husk were analysed by using ICP-OES (Inductively coupled plasma - optical emission spectrometry) in an external laboratory.

RESULTS AND DISCUSSION

According to figure 1, at lower temperatures, system takes less time to obtain the equilibrium point, but amount of ash removed is less. As temperature rises time for equilibrium point is also increases with increasing ash leaching.

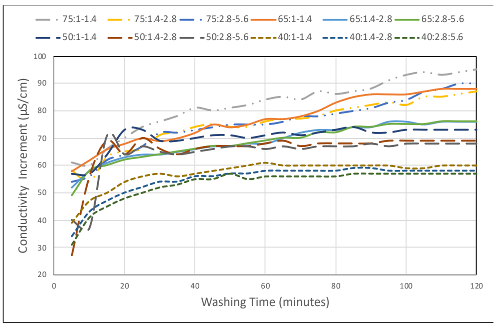

Figure 1 – Conductivity Increment Vs Time

Temperatures above 65^0C takes more than 2 hours to achieve relevant equilibrium point. Size of the particle size is also crucial according to the figure 1, as the smaller size has much higher leaching properties compared to other two sizes.

As temperature rises the leaching ability of smaller sizes increases at higher rate compare to other two sizes. Particle size does not significantly affect the washing time; however, the washing time of Rice Husk clearly depends on the washing temperature.

Figure 2 indicates, with decreasing particle size and increasing temperature, the removal of ash is high. It is also apparent that reduction of particle size has more effect on removal of ash as 40^0C 1-1.4mm size has higher removal than 75^0C 2.8-5.6mm sample.

Final conductivity at the end of 2 hours of the experiments, can be related to the actual ash removal content which analysed from the combustion of the washed sample. Figure 3 can be developed with ash removal percentage vs final conductivity value which shows a linear relationship with errors within ±5%. However, to develop a sound mathematical function, acquisition of more data is required.

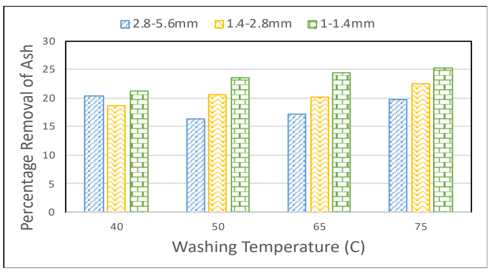

Figure 2 – Percentage Removal of Ash

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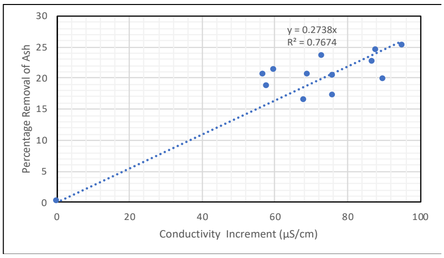

Figure 3 – Percentage Removal of Ash vs Final Conductivity

For ease of analysis, it is assumed that all components in ash sample are in their stable oxide form. The elemental analysis only conducted for the samples of raw unwashed, 40^0C 2.8-5.6mm size and 75^0C 1-1.4mm size. From figure 4, Fe_2O_3 and Al_2O_3 has removed approximately 40% while 70% of P_2O_5 has removed through water washing. K_2O has the highest removal which is 90% of initial K content. Even the presence if Ti is small amount, water washing could be able to remove a significant fraction (~40%). Ca, Mg and Na has increased in washed sample. This is due to use of normal tap water instead of distilled or demineralized water. Carrillo et al. also achieved similar results which was conducted to sorghum biomass using city water supply. This raise a significant issue in industrial scale pre-treatment using water, because distilled water is expensive. Thus, it is more susceptible to increase in Ca, Mg and Na content in solid biomass fuel based on the source of water, if water is not treated to remove these constituents.

Zevenhoven et al. used an index that also incorporates the association of ash-forming elements based on soluble

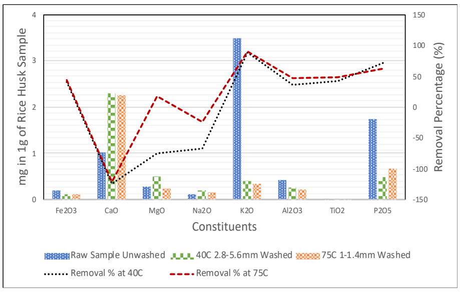

Figure 4 – Compositions of Samples

alkaline and alkaline-earth metals. The formula for calculation of fouling index is as follows,

Fouling index (%) = (Na_2O+K_2O+CaO+MgO)/Total Ash x 100%

According to the formula the fouling indices are 2.579%, 2.331%, 2.158% for Raw, 40^0C and 75^0C samples respectively. With increasing temperature, clearly the fouling tendencies has reduced.

CONCLUSION

The time for equilibrium in ash leaching of rice husk, increases with temperature but higher removal of ash can be achieved. The removed ash and the conductivity increment in the leachate indicates a linear relationship. Much higher ash removal can be achieved by reducing the particle size rather increasing the washing temperature. Removal of K is more effective in hot water washing; However, the source of the washing water affects the variation of Ca, Mg and Na content in rice husk. Overall the fouling index for rice husk reduces with increasing temperature of washing water.

REFERENCES

1. Carrillo, M. A., Staggenborg, S. A., & Pineda, J. A. (2014). Washing sorghum biomass with water to improve its quality for combustion. Fuel, 116, 427-431.
2. Deng, L., Zhang, T., & Che, T. (2013). Effect of water washing on fuel properties, pyrolysis and combustion characteristics,. Fuel Processing Technology, 712-720.
3. Gudka, B., Jones, J. M., Lea-Langton, A. R., Williams, A., & Saddawi, A. (2016). A review of the mitigation of deposition and emission problems during biomass combustion through washing pre-treatment. Journal of the Energy Institute, 89(2), 159-171.

Zevenhoven, M., Yrjas, P., Skrifvars, B.-J., & Hupa, M. (2012). Characterization of Ash-Forming Matter in Various Solid Fuels by Selective Leaching and Its Implications for Fluidized-Bed Combustion. energy & fuels,6366−638