Mineral Washing from Rice Straw to Improve its Combustion Properties

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Abstract. Indonesia has abundant potential for rice straw which can be developed as an alternative fuel. However, rice straw has an ash content with a high mineral content which can cause problems in applications involving high temperatures. This study aims to determine the effect of washing rice straw on the fuel quality improvement of rice straw. Sun-dry rice straw that has been cut into 1-2 cm is soaked in tofu industrial wastewater at a ratio of 0.5 kg in 10 L. Sampling for the measurement of ash and mineral content was carried out at 0 (without treatment), 3.75, 7.5, 15, 30, 60, 120, and 720 min. Ashing was carried out using a furnace at a temperature of 550 °C for 2 hours. The ash was then analysed using XRF Spectrometry to determine its mineral content. Measurement of the caloric value of rice straw was carried out using a bomb calorimeter. Results showed that soaking straw in tofu wastewater decreased the ash content from 16.0 to 13.67 (% DS) and increased the calorific value from 13.60 MJ/kg (without soaking) to 15.77 MJ/kg (soaking by 720 min.). Soaking was also able to reduce important minerals such as K (17.94% to 9.69%), S (3.40 to 2.06%), Cl (0.91% to 0.3%).

1. Introduction

As the third largest rice producing country in the world [1], Indonesia is a country rich in rice straw waste. The rice harvesting process produces a by-product in the form of straw. Rice straw is the largest component of wastes resulted from harvest and post-harvest activities of rice. This is because rice straw makes up about half of the rice plant [2]. Straw covers the part (stem) that is left during harvesting and straw after the grain is shed. Dry straw production ranges from 2.3 t/ha [3] to 3.86 t/ha [4]. In 2019, Indonesia's rice harvest area reached 10.68 million ha [5], so that with an average straw production rate of 3.0 t/ha, the total potential for Indonesian rice straw is 30.04 million ton of dry matter. Rice straw has an average calorific value of 14.32 GJ/t, so the energy potential of rice straw is 459 PJ/year, equivalent to 12.4 million kiloliters of diesel fuel. Therefore, rice straw can be an alternative renewable energy source to replace fossil energy in order to reduce greenhouse gas emissions and avoid local pollution due to open burning.

However, rice straw has intrinsic properties that are detrimental as a fuel. Haryanto et al. (2019) mentioned that one of the striking disadvantages of rice straw compared to other biomass is the high ash content (up to 22.1%) which reduces the calorific value [6]. In addition, rice straw is a poor fuel, especially for systems operating at high temperatures due to its intrinsic characteristics such high minerals content, especially Si and K [7]. These minerals in ash are responsible for various undesired reactions in the combustion system. The concentration of ash and the high content of silica and alkali metals in rice straw results in agglomeration, fouling, and slagging of boiler components which results in decreased system efficiency [8] and failure of most furnaces and a boiler. This problem has hampered the utilization of straw for large-scale boilers, even in areas where the straw sources are close to a boiler. The high silica content in rice straw causes the chopping machine components to wear out quickly. Rice straw is also very difficult to burn, especially in furnaces designed for power generation due to the formation of deposits. Si and K are transformed into K_2SiO_3 or other types of silicates at elevate temperatures, while silicates are also formed with other alkali and alkaline metals. Alkaline silicates have melting point temperatures as low as 800 °C [9] and therefore cause problems in gasification operations in form of channelling and defluidization [10]. These deposits inhibit the rate of heat transfer, triggering scale formation in the furnace and in the nests, making fuel feed and ash removal difficult. Thus, removal of alkali metals in particular, potassium, is an important treatment before rice straw is used for combustion fuel.

One way to reduce the mineral content in straw is through the washing or leaching process. Washing is able to significantly decrease minerals content. For example, it was reported that washing oil palm empty fruit bunch have reduced ash content by 81% from 5.43% to 1.03% (db) [11]. This study aims to evaluate washing of rice straw using wastewater from tofu industry. Due to its high organic content [12], tofu wastewater is acidic and is expected to have good ineral leaching.

2. Materials and methods

2.1. Materials

Rice straw is obtained from harvested rice fields, then dried under the sun to dry so that it does not rot easily when stored. The dried straw is then chopped about 1-2 cm and stored in a tightly zipped plastic bag until use. Tofu waste water is obtained from the household tofu industry areas in Gunung Sula, Bandar Lampung. Wastewater samples were taken before the wastewater is discharged into the sewage. The wastewater was acidic and is intended because acidic washing effectively removes water-soluble elements from the biomass [13].

2.2. Leaching Process

Rice straw is soaked in tofu wastewater with a ratio of one part by weight of straw into 20 parts by volume of tofu wastewater. In this study 500 grams of straw was soaked in 10 L of tofu wastewater. The measured parameters were the straw moisture content, pH of tofu waste, ash content, ash composition and calorific value of straw. Measurements were made at various soaking times, namely 0 (without soaking), 3.75, 7.5, 15, 30, 60, 120, and 720 min. The calorific value of straw is compared between the beginning (without soaking) and after 720 minutes of soaking time.

2.3. Analysis and Measurement

The measurement of the parameters are conducted as the following:

a. Water content (*MC*) of rice straw was measured gravimetrically by drying in an oven (Memert UM 500) for 24 hours at 105 °C. Moisture content of rice straw is calculated from:

$$MC = 100\% \times (WS - DS)/WS \quad (1)$$

where *WS* is wet mass of rice straw (before drying) and *DS* is dry solid of rice straw (after drying).

b. Acidity (pH) of tofu wastewater was measured by using a pH-meter. Measurement was conducted at various soaking time as previously mentioned.

c. Ash content was measured at various soaking time during the leaching process. Before the ash content is measured, the sample is dried in an oven for 24 hours at 105 °C. Then the dried sample (Mk) was put into the furnace (Banrstead Thermolyne 1300) for 2 hours at temperature of 550 °C. After cooling in a desiccator, the sample is weighed (Mt). Ash content is calculated by the formula:

$$\text{Ash} = (\text{Mt}/\text{Mk}) \times 100\% \quad (2)$$

d. Ash composition was measured at various time soaking during the leaching process. In this case rice straw ash samples was sent to Universitas Negeri Padang (West Sumatera) for further analysis using XRF (X-Ray Fluorescence) Spectrometry.