



ELSEVIER

Contents lists available at ScienceDirect

Chemical Engineering Research and Design

journal homepage: www.elsevier.com/locate/cherd

Characterization of rice husk varieties in Uganda for biofuels and their techno-economic feasibility in gasification

P.W. Olupot^{a,*}, A. Candia^b, E. Menya^c, R. Walози^b

^a Department of Mechanical Engineering, College of Engineering, Design, Art and Technology, Makerere University, PO Box 7062, Kampala, Uganda

^b Agricultural Engineering and Appropriate Technology Research Centre (AEATREC), PO Box 7144, Kampala, Uganda

^c Department of Biosystems Engineering, Gulu University, PO Box 166, Gulu, Uganda

ARTICLE INFO

Article history:

Received 20 June 2015

Received in revised form 2

November 2015

Accepted 18 November 2015

Available online xxx

Keywords:

Rice husks

Energy

Thermo-chemical

Biochemical

Gasification

ABSTRACT

This study set out to investigate the properties of husks from ten selected rice varieties in Uganda. Rice samples were collected from one geographical region, identically milled, and the husks ground for analysis. Characterization involved physical, proximate, ultimate, thermal, lignin, hemicellulose and cellulose composition analyses. The samples exhibited bulk density of 88.8–124.3 kg m⁻³, moisture contents 9.2–11.2%wb, volatile matter contents 58.8–66.4%wb, ash contents 15.9–25.6%db, fixed carbon 14.8–17.8%db, carbon contents 30–34.5%db and carbon to nitrogen ratios of 55:1–87:1. The higher heating values (HHV) ranged between 12.8 and 14.5 MJ/kg, lignin 10.6–13.5%db, hemicelluloses 11.4–20%db and cellulose 31–37%db. The low bulk densities and lignin contents necessitate that the husks should be densified in the presence of binders. The C/N ratios are higher than required for either biogas production or composting. The HHV, ash content and non-concentration of rice husk generation offer prospects for converting rice husk fuel into energy using down-draft gasification for systems capable of 30–500 kW. Results demonstrate that a gasifier generator system of 250 kW operating for 8 h a day for 350 days in year requires 5.8 t of husk per day to produce 700 MW h/year. This results in annual electricity production cost saving of US\$98,000 when compared to equivalent diesel plant, with payback period of 2.5 years.

© 2015 The Institution of Chemical Engineers. Published by Elsevier B.V. All rights reserved.

1. Background

Uganda has registered recent successes in rice production making it a potential rice basket for Eastern Africa (Africa Rice Center, 2013). The remarkable rice boom in Uganda is attributed to good farming practices, premium market prices, and favorable policies that have stimulated large private investment in the rice sector over the last few years. As a result, paddy production jumped from about 120,000 t in 2002 to more than 220,000 t in 2011 (Africa Rice Center, 2013). Rice

husk (RH) is the waste generated during the milling process of rice. On average 20% of the paddy rice is husk (Giddel and Jivan, 2007), giving an annual global total production of about 144 million Mt (FAO, 2011). Several conversion techniques exist that can be utilized to extract energy from rice husks. They include thermo-chemical, bio-chemical and physico-chemical conversion techniques (Delivand et al., 2011). Besides the use of rice husk for production of biofuel, it can also be used to manufacture bio-products such as particle boards, insulation boards, ceiling boards and as a fertilizer (Clemens and Dato,

* Corresponding author. Tel.: +256 701658768; fax: +256 414531048.

E-mail addresses: polupot@cedat.mak.ac.ug (P.W. Olupot), alphonsecandia@gmail.com (A. Candia), E.menya@gu.ac.ug (E. Menya). <http://dx.doi.org/10.1016/j.cherd.2015.11.010>

0263-8762/© 2015 The Institution of Chemical Engineers. Published by Elsevier B.V. All rights reserved.

2009; Vadiveloo et al., 2009). Moreover, the burning of rice husk under controlled conditions generates rice husk ash (RHA) which is a valuable material for industrial applications due to its high silica content. RHA contains 87–97% silica which can serve as a source for many silicon-based materials (Rozainee et al., 2008). In addition, the ash from biomass fuel contains only trace amounts of heavy metals, which makes them fairly easy to dispose off and can also be a good fertilizer (Olanders and Steenari, 1994).

Despite the potential benefits associated with rice husk, only about 17% of the rice husk produced globally, find an application per year (Ankur, 2010), suggesting that very large quantities become a waste. The common practice of burning rice husk without heat recovery and openly dumping of these wastes still prevails especially in developing countries to which Uganda is no exception (UNEP, 2009). In other places, the rice husk is left to rot in situ, subsequently emitting greenhouse gasses (GHG) and causing other environmental problems (Jeng et al., 2012). Moreover in many developing countries, the utilization of rice husk is constrained by unavailability of improved technology. The chemical differences between biomass components directly influence their chemical reactivities. This is why the knowledge of the total amount of each component is crucial to predict the efficiency of a biomass conversion process (Ando et al., 2000). Similarly, the utilization of RHA depends on the composition of ash which in turn depends on the plant species, growth conditions and ash fraction (Demirbas, 2005). This study therefore set out to investigate the properties of rice husk from ten selected rice varieties in Uganda. This was done so as to precisely determine the possible technologies for potential utilization of the husks from each rice variety. Additionally, an economic comparison was made to evaluate the benefits of electricity production from rice husks as opposed to diesel engine generators.

2. Materials and methods

2.1. Sample collection and preparation

Ten varieties of rice grains were collected from one geographical region in Uganda. The samples were de-husked in an identical de-husker. Approximately one kg of husk from each rice variety was carefully kept in separate sampling bags. The samples were each subsequently milled to pass through a 1 mm mesh sieve using a 1093 cyclotec sample mill for subsequent characterization.

2.2. Characterization of rice husk varieties

The characterization work involved bulk density, proximate analysis, ultimate analysis, lignin, hemicellulose and cellulose analyses. Three experimental runs were conducted for each parameter and then the average value obtained. The various analytical tests carried out using the finely ground samples from each rice husk variety are described in the following sections.

2.2.1. Bulk density and moisture content

The bulk density was determined by loosely filling a cylindrical container of 500 ml with biomass whose weight was determined by weighing. The bulk density was then determined

using Eq. (1). The moisture content was determined according to DIN 51718 standard.

$$\text{Bulk density, } \rho = \frac{\text{mass of biomass}}{\text{volume of container}} \quad (\text{kg/m}^3) \quad (1)$$

2.2.2. Proximate analysis

The proximate analysis was used to determine the volatile matter (VM), fixed carbon (FC) and ash content. DIN 51720 standard was used to determine the VM content in which 2 g of the sample in a covered crucible was heated in a muffle furnace at a temperature of 900 °C and held at this temperature for 7 min. After heating for 7 min without air exchange, the crucible was removed from the furnace, and the sample allowed to cool. The decrease in weight corresponds to the proportion of volatile matter. The percentage weight loss was determined using the integrated program in the thermogravimetric analyzer (TGA).

The ash content was determined according to DIN 51719 standard in which 10 g of the sample in a crucible was placed in the muffle furnace and heated gradually to the ignition temperature of 600 °C for 2 h. The weight was measured every after 2 h until when a constant mass was attained. The ash content was determined as the weight difference before and after the burning and this was determined using the integrated program in the thermo-gravimetric analyzer (TGA).

The percentage content of fixed carbon was determined by difference as shown in the following equation:

$$\% \text{fixed carbon (db)} = 100 - [\% \text{VM (db)} + \% \text{ash (db)}] \quad (2)$$

2.2.3. Ultimate analysis

The ultimate analysis was carried out in order to determine the elemental composition of the rice husk. The elements of interest included carbon (C), hydrogen (H), nitrogen (N) and sulphur (S). The C, H and S were determined using ELTRA Analyzer CHS-580 using the integrated ELTRA GmbH software on 200 mg of sample. The N was determined separately using the Kjeldahl method, which is based on the conversion of the fuel bound nitrogen to ammonia (NH₃), which is subsequently separated by distillation and determined by titration using HCl solution and methyl red as indicator.

2.2.4. Heating values of the husk

The heating value of biomass was determined using a digital bomb calorimeter (model: IKA C 2000) in which samples weighing 400–600 mg were placed in the bomb calorimeter and subjected to complete combustion in an adiabatic environment. The higher heating value (HHV) was determined using the integrated bomb calorimeter software. Additionally, the empirical correlation developed by Channiwala and Parikh (2002) given in Eq. (3) was also used to compute HHV, and the results were compared with those obtained from the experimental method.

$$\text{HHV} = 34.91C + 117.83H - 10.34O - 1.51N + 10.05S - 2.11\text{Ash} \quad [\text{MJ kg}^{-1}] \quad (3)$$

where C, H, S, O, N, and Ash are percentages of carbon, hydrogen, sulfur, oxygen, nitrogen, and ash as determined by ultimate analysis on a dry basis.

Download English Version:

<https://daneshyari.com/en/article/7006944>

Download Persian Version:

<https://daneshyari.com/article/7006944>

[Daneshyari.com](https://daneshyari.com)