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Production and characterization of agro-based briquettes and estimation of calorific value by regression analysis: An energy application

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ABSTRACT

Biomass in the original form having low bulk density results in huge transportation & storage costs, and cannot be used as an effective combustible fuel. Densifying biomass by briquetting/pelletizing technology helps to reduce the above said problems and improves the effectiveness of biomass as combustible fuel. In the present study, briquettes were produced by using rice husk and carbonized rice husk with starch and bentonite clay as binders. The bulk density and compressive strength of briquettes produced were determined. It was observed that bulk density values of briquette samples increased with increase in binder percentage in the mixture up to 6% and decreased with further increase in binder concentration. Similar trend was also observed for compressive strength of briquettes. Proximate analysis of briquettes was evaluated as per the standard methods. A mathematical equation to estimate calorific value of biomass briquettes based on the proximate analysis of briquettes was developed by using regression analysis. It can be inferred that the predicted data from the proposed model closely match with the experimental data with a R^2 value of 0.94 and root mean square deviation (RMSD) of 0.0659.

1. Introduction

Fossil fuels, the major energy sources of the world are nonrenewable and their reserves are limited. Fossil fuels release tremendous amount of greenhouse gases into the atmosphere [1] and using them to meet the thermal energy demands place a heavy burden on the economy of developing countries like India [2]. Adopting the use of bio-energy, a renewable source of energy is hence highly recommended [3,4]. Biomass or organic material like paper, paperboard, byproducts from agricultural and forest based industries are potential source of energy. Biomass can be formed into biomass briquettes that can contend or coexist with traditional fuels [5]. Biomass is promising and sustainable energy resource with minimal greenhouse gas emissions and can solve fossil fuel problems of future. The biggest challenge poised is efficient use of biomass and increase of calorific value/kg of biomass [6]. The higher heating value (HHV) is the key economical factor that can increase biomass application in energy industry [7]. Biomass, in its original form has low bulk density values and results in huge transportation and storage costs. Biomass when used as combustible fuel releases emissions in the form of particulate matter in the atmosphere. Increasing the density of the biomass either by briquetting or pelletizing technology increases bulk density, improved ease of handling [8,9] and greater hardness briquettes/pellets. It also improves the burning efficiency and makes biomass briquettes effective combustible fuels [8,10]. Densification of biomass into pellets or briquettes is one of the approaches, pursued worldwide, towards improved and efficient utilization of agricultural wastes. Bulk density is one of the important property detrimental in designing logistic systems for biomass handling. The moisture content, shape, size, surface characteristics and particle density are the major factors affecting the bulk density. Biomass is briquetted to ease handling and increase density of biomass to be used as fuel. Briquetting involves compressing biomass with or without binder and other additives that helps the briquette to burn. Loose biomass of bulk density 0.1 to 0.2 g/cm^3 increases to 1.2 g/cm^3 during the process of briquetting. The direct burning of loose biomass in conventional grates yields low thermal efficiency and suspended particulate matter in the flue gases leads to air pollution. So far researchers are mainly focused on biomass conversion technologies. There exists scope for R&D works on biomass densification development [11]. Compression process allows the biomass to burn longer than if it were left loose. Compressed biomass can burn at the same temperatures and for an equal or more duration than its constituents. Raw materials for the

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compression process are separated based on their burning properties and characteristics and then shredded into a coarse powder. This powder is then forced through a high or low-pressure power-driven press which heats the powder and forces it through a die. Dependent on the need of the end user, the briquettes are shaped into different shapes and sizes. Briquetting can be achieved by reciprocating ram/piston press or screw press. In process of briquetting, selecting quality raw material is important factor in ascertaining commercial success. Briquetting process is accomplished by using natural material lignin acting as a binder in high pressure press. Additional binding material is avoided as lignin is released on application of high pressure. Biomasses lacking adequate plasticity may need introduction of binder to form briquette, holding briquette together during storage and transportation. The quality and cost of the briquettes depends on binders and additives used during briquetting. During the briquetting process, biomass particles are coated with binder, wet pressed and dried. Starch, clay and gums are commonly used briquette binders. Other additives such as accelerants, ash-whitening agents, press release agent and fillers also may be added. Biomass species have very wide range of biomass materials such as agricultural residues, herbaceous and woody biomasses, nut shells, stem, husks and pulps. These biomass possess wide range of physical properties i.e., fixed carbon, ash content, moisture and volatile matter. Hence developing techniques and empirical equations to predict the higher heating values (HHV) is a matter of interest to many. In India rice production accounts for 14% of world's rice production [12] and hence a large amount of residue rice husk is generated. Rice husk, an agro-based residue is generated at the rate of approximately 0.046 tons per ton of rice produced [13]. India is officially forecast to collect a record of 163.3 million tons (108.9 million tons, milled basis) in 2016 [14]. Several researchers are trying to explore the possibilities of converting the biomass into value added & useful income-generating products [15]. In the present work, initial trials were conducted for locally available biomass and binders. Different biomass/binder ratios were tried and a suitable range of biomass/binder ratios were chosen. During experimentation wet process with starch (organic) and bentonite (inorganic) as binders have adopted. The briquettes produced were tested for durability and bulk density. A mathematical relationship to estimate/predict calorific value based on proximate analysis was developed and validated.

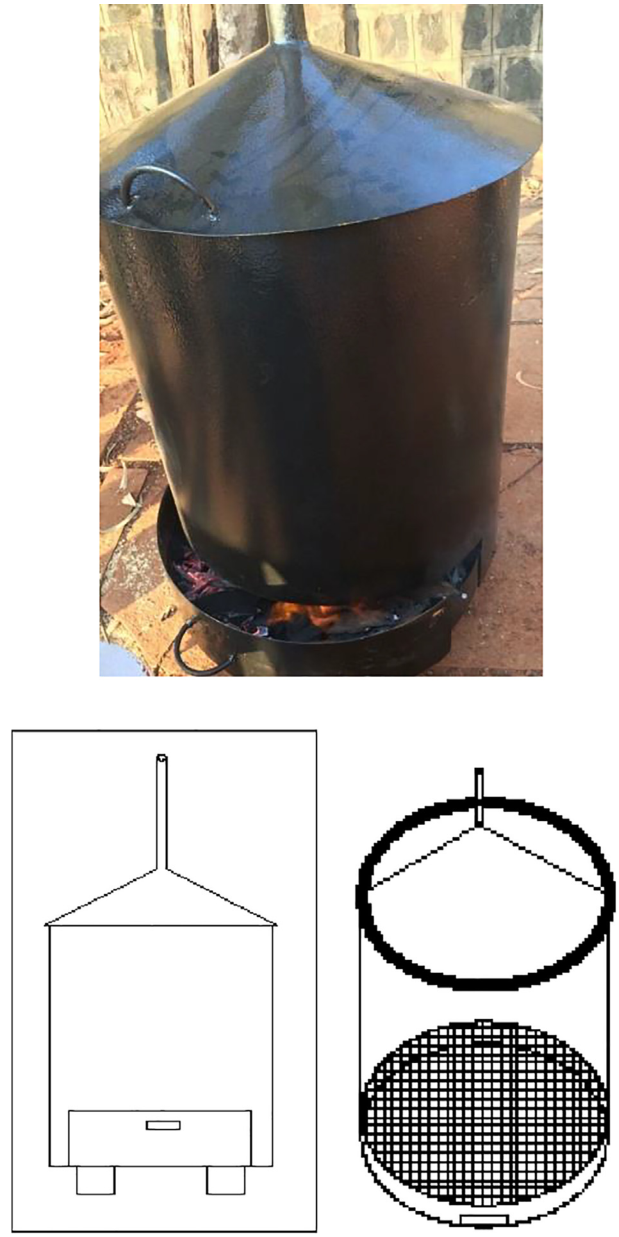

Fig. 1. Photograph and Sketch of pyrolyzer.

2. Materials and methods

2.1. Biomass

Rice husk was collected from the local rice mill and sun dried for a day. The rice husk was carbonized in a pyrolyzer. The pyrolizer used for the carbonization of rice husk was fabricated locally and the photograph and sketch of the same is shown in Fig. 1. The pyrolyzer is a portable cylindrical structure with lid at the top and tray at the bottom to close the lower portion of the drum and also to fire the biomass. Above the tray an iron perforated sheet with holes is fixed. Sun dried biomass was placed in the pyrolizer and the top portion is covered with airtight lid. Small amount of biomass was placed in the tray to ignite in the pyrolizer and tray was closed tightly. After partial combustion, the pyrolizer lid was opened and water was sprinkled on the char. The char was collected and sun dried for two days. For the production of briquettes using rice husk, the rice husk was ground to fine powder passing through 1.70 mm and retained on 0.85 mm. The surface morphology of the rice husk and carbonized rice husk was analyzed using scanning electron microscopy (SEM; Zeiss Supra 55 PP) as shown in Figs. 2 and 3, respectively. The morphological structure of the rice husk and rice husk char showed non uniform short fibrous and coarser structure. Fibrous texture of rice husk and char favors the biomass agglomeration. The SEM- analysis showed that the microstructure of the rice husk char was highly heterogeneous and at higher temperatures, the low-melting oxides fuse with silica on the surface of the rice husk char and form glassy or amorphous phases as reported by [16].

2.2. Methods of briquettes production

A cylindrical briquetting die with an inner diameter of 50 mm and a height of 50 mm was filled with a known quantity of thoroughly mixed biomass and binder. A hand press machine was used to compress the biomass raw material. The briquettes so produced were sun dried for a week. Sample briquettes are shown in Fig. 4. Proximate analysis (volatile matter content, ash content, fixed carbon) [17], calorific values and mechanical strengths of briquettes were determined as per the standard procedure.