Biomass Energy Potential for Domestic Combustion in Myanmar: Characterization of Biomass Fuel Pellets

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Abstract. Biomass is the largest contributing energy source in Myanmar due to low cost and environmental consequences. Myanmar annually produces 5.77 million ton of rice husk on 26.21 million ton of paddy rice production and 114,975 cubic ton of wood left in the forest on annually 365,000 ton of wood logs. Myanmar still needs more energy consumption to develop the agricultural economy and biomass energy in the future of the country although electricity supply is expected to increase to 55 percent in 2021-2022 FY. In this work, the chemical composition and energy composition of rice husk and assorted wood were determined. And then, the physicomechanical properties of rice husk pellets without doing size reduction but assorted wood pellets with size reduction were analyzed and compared these results with ISO 17225-6 and ISO 17225-2 standards. The assorted wood lignin content was higher than of rice husk. The ash content of rice husk was higher than that of assorted wood due to large amount of ash forming compounds such as silicon dioxide and potassium oxide in rice husk. The bulk density, net calorific value, and mechanical durability of assorted wood pellets were higher than that of rice husk pellets due to the larger amount of lignin in assorted wood. The physicomechanical properties of produced pellets were complied with ISO standards.

1. Introduction

Biomass derived from plants and animal organism materials is a carbon natural source of energy. Biomass can produce biogas, liquid fuels and electricity due to a versatile fuel [1]. Biomass as an agricultural waste and a forestry waste mainly uses for cooking and cottage industries in Myanmar because of limitless supply. According to FAO FRA 2015, about 42.92 % and 19.54 % of the country’s total land area (6.76 km²) has still covered with forest and agriculture, respectively [2]. Myanmar Statistical Yearbooks reported that the permanent forest estate decreased by 0.1 % in 2015-2016 as compared to the previous period [3].

Based on Mirror News (28th May, 2017), Myanmar Timber Corporation has been extracting about 15,000 cubic ton of teak logs and 350,000 cubic ton hardwood logs within 2017-2018 budget year. A teak tree on the average produces 68.5 % of marketable size, 18.4 % of rejection and 13.1 % of tops and lops, respectively. Thus, it shows that about 31.5 % of the tree was left in the forest [4]. Logging activities in the forests, wood processing industries, and sawmill generate a huge amount of wood wastes annually.

Myanmar has produced 5.77 million ton of rice husk with an annual paddy rice production of 26.21 million ton in 16.72 million harvested acres [3-5]. The thirty percent of this rice husk is consumed in
rice husk gasifier and boiler-based system to produce electricity and heat. The remaining 70% of the rice husk is large challenges for disposal in the rice milling because bulk density of rice husk is 130.18 kg/m$^3$ [6]. Then, 1.16 million ton of maize was produced 179 thousand acres of sown in 2016. Cobs are used to make charcoal for fuel.

The production of groundnut was 1.52 million ton, produced in 2.35 harvested acres [3]. This groundnut shell (25-30% of the total weight) is used directly for fuel in small-medium enterprise oil production industrials. Moreover, the groundnut shell is also used as soil amendment, manure and mulch in Myanmar. Sesamum was 827.4 thousand ton annually produced in 3.73 million acre of harvested sesamum in 2016 [3]. Although there are many forest residue and agricultural residue, the rice husk and wood residue should consider for the further biomass energy potential for domestic combustion in Myanmar due to the huge amount of residue produce annually and its low bulk. To be more efficient in utilization of biomass sources, Myanmar will need to incorporate partnerships among industry-academia-government collaboration between Myanmar and not only international organizations but also national organization [7].

In this case, the pelletization of biomass is critical for meeting handling, storage and transportation optimal conditions, as well as complete combustion in furnaces [8]. The pellets mills are commonly used to produce biomass pellet whereas the product pellets quality depends on the operation parameters such as die temperature, compression ratio of press diameter to die channel length, biomass compositions such as cellulose, hemicellulose, and lignin, biomass particle size, ash content, and moisture content [9]. As observed in previous research work, net calorific value and bulk density of produced rice husk pellets with moisture content (7.48 ± 0.1514 wt. %) partially fulfilled according to the ISO 17225-6 standard. For this, the effect of biomass composition on rice husk and assorted wood pellets are studied on net calorific value and bulk density and compared these data with ISO 17225-2 and ISO 17225-6 standards.

2. Experimental

2.1. Preparation of Materials

Rice husk and assorted wood species were collected just before entering the pellet mill and pellets obtained from each species on the vibrating screens with a round-hole sieve (3.18 mm) were amassed for the further analysis. Rice husk and assorted wood species were ground with ball mill into particles of less than 850 µm, respectively. After mesh sieving, the sample size of particle from 212 to 600 µm were obtained and used for analysis. These samples to analysis the fuel properties were supported by Myanmar Biomass Power Co., Ltd, located in Bago Division, the third largest producer of paddy in Myanmar.

2.2. Pelletization

The pelletization process was implemented with Yulong 6th generation XGJ 850, 220 kW. The capacity of pelletizer with ring die using three rollers was 2.5-3.5 ton/h. Rice husks obtained from the rice mills were used without doing any treatments such as drying and size reduction. Assorted wood species acquired from various waste from the forestry industry like saw dust, shaving, veneer waste and off cuts were cut with cutting machine consisting 49 knives and sieved to get the desired size. The moisture contents of rice husk and assorted wood species before entering to pelletizer were 12.54 wt. % and 12.28 wt. %, respectively. The compression ratios for rice husk, and for assorted wood species, which is the ratio of press diameter to die channel length, were 1:5.5 and 1:8, respectively. The pellet temperature and appearance after discharge from the mill was about 93 ± 2 °C and soft due to lignin in biomass fuel. The pellets extruded through the die holes were cooled with a conveyor belt having 3.18 mm of sieves. The clean and dust-free pellets transported from belt conveyor were packaged in bags for further analysis. Figure 1 shows the photos of manufactured rice husk pellets and assorted wood pellets.
2.3. Analytical Methods

The chemical compositions, proximate, and utilization analysis of rice husk, and assorted wood species were analyzed according to the analytical procedure of the Verband Deutscher Landwirtschaftlicher Untersuchungs- und Forschungsanstalten (VDLUFA, ANKON method [10, 11], the American Society for Testing and Materials (ASTM) [12-14], a Flash Smart CHNS analyzer (Thermo Fisher Scientific, USA). Inorganic constituents of rice husk, and assorted wood species were measured with ZSX Primus IV, WDXRF (Rigaku). A bomb calorimeter (Parr 6200, USA at GNDTP, Bathinda) was used to determine the higher heating value (MJ/kg) of rice husk pellets, and assorted wood pellets. The bulk density and durability of pellets were analyzed according to the International Organization for Standardization (ISO) 17828 (EN15103) [15, 16] and ISO 17831-1 (ASAE S269.4 standard) [17, 18]. The analysis was repeated at least three times, and the average value was described in this work.

3. Result and Discussion

Table 1 shows the chemical composition mainly composed of celluloses, hemicellulose, and lignin, and an inorganic constituent of rice husk and assorted wood used for the manufacturing of fuel pellets. It can be observed that crude fibre content in assorted wood was higher than that in rice husk. The cellulose contents in the rice husk and assorted wood were 44.75 % and 41.15 %, respectively. Cellulose in biomass does not serve as a binding agent during pelletization process but the lignin can perform as a basic binding material to form pellet. The assorted wood lignin content was higher than the rice husk lignin content that results in increase the bonding activity of cellulose with less energy. Rice husk was high in silicon dioxide and potassium oxide contents but low in calcium oxide content by comparing with assorted wood. The high content of potassium oxide and silicon dioxide compound could happen a variety of severe ash related problems such as alkali induced slagging, silicate melt induced slagging, and agglomeration during the combustion of biomass fuel.

The proximate and ultimate analysis of rice husk and assorted wood is described in Table 2. It can be seen that the rice husk ash content was higher than the assorted wood ash content due to large amount of ash forming compound in rice husk. The carbon and hydrogen in biomass are the special element for heating value and if the nitrogen and sulfur contents in biomass are low, these contents could be negligible. These value are influence the heating value of biomass fuel. The carbon and hydrogen contents of assorted wood were comparable to that of rice husk, whereas the carbon and
hydrogen contents of assorted wood were higher than that of rice husk. The higher content of nitrogen and sulfur in biomass combustion can lead to higher formation of NO\textsubscript{x} and SO\textsubscript{x}.

**Table 1.** Chemical compositions and inorganic constituents of rice husk and assorted wood based on dried basis.

| Chemical compositions, wt. % | Rice husk | Assorted wood | Inorganic constituents, wt. % | Rice husk | Assorted wood |
|-----------------------------|-----------|---------------|--------------------------------|-----------|---------------|
| Cellulose                   | 41.15     | 44.75         | Silicon dioxide                | 92.96     | 10.90         |
| Hemicellulose               | 21.10     | 11.05         | Potassium oxide                | 3.85      | 2.94          |
| Lignin                      | 15.27     | 32.23         | Calcium oxide                  | 0.76      | 29.90         |
| Fat                         | 0.05      | 2.28          | Sulfur trioxide                | 1.63      | 13.90         |
| Crude protein               | 0.25      | 1.48          | Iron oxide                     | 0.41      | 1.51          |
| Crude fibre                 | 4.29      | 63.30         | Manganese II oxide             | 0.32      | 3.22          |

**Table 2.** Proximate and ultimate analysis of rice husk and assorted wood

| Proximate analysis (wt. %) | Rice husk | Assorted wood | Ultimate analysis (wt. %) | Rice husk | Assorted wood |
|---------------------------|-----------|---------------|---------------------------|-----------|---------------|
| Moisture                  | 12.54     | 12.28         | Carbon, C                 | 38.45     | 49.02         |
| Ash                       | 16.14     | 0.98          | Hydrogen, H               | 5.20      | 6.39          |
| Volatile matter           | 62.95     | 79.25         | Nitrogen, N               | 0.14      | 0.23          |
| Fixed carbon              | 8.37      | 7.49          | Sulfur, S                 | 0.06      | 0.02          |

| Oxygen, O                 | 56.15     | 44.34         |

**Table 3.** Physical and mechanical properties of rice husk pellets, and assorted wood pellets and ISO 17225-6 and ISO 17225-2 specifications of pellets produced on an herbaceous biomass, and by-products and residues from wood processing industry

| Fuel properties           | Rice husk pellets | Assorted wood pellets | ISO 17225-6 | ISO 17225-2 |
|---------------------------|-------------------|-----------------------|-------------|-------------|
| Physical property         |                   |                       |             |             |
| Diameter (D), mm          | 8                 | 8                     | From D06 to D10 | D08, 8 ± 1  |
| Length (L), mm            | 10 < L ≤ 75       | 10 < L ≤ 75           | 3.15 < L ≤ 40 | 3.15 < L ≤ 40 |
| Moisture (M), wt. %       | 10.14             | 10.05                 | M 12 ≤ 12   | M 10 ≤ 10   |
| Bulk density (BD), kg/m\textsuperscript{3} | 775.14           | 825.08                | BD 600 ≥ 600 | BD 600 ≥ 600 |
| Net calorific value (Q), MJ/kg | 16.09           | 19.21                 | Q 14.5 ≥ 14.5 | Q 16.5 ≥ 16.5 |
| Mechanical property       |                   |                       |             |             |
| Durability, DU (%)        | 98.32             | 99.04                 | DU 97.5 ≥ 97.5 | DU 96.5 ≥ 96.5 |

Table 3 shows the physicomcal and mechanical properties of produced rice husk pellets, and assorted wood pellets, and describes a comparison of those with ISO specifications [19, 20]. It could be seen that the moisture contents of rice husk pellets and assorted wood pellets decreased after pelleting due to the removal of water stored in space within the dead cells and cell walls of biomass as pellets exit from the die. Rupar-Gadd and Fross [21] reported that optimum moisture content for solid biofuels was (8-10 wt. %) to improve the mechanical durability and heat value. The assorted wood pellets bulk density was higher than that of rice husk pellets because of dependence on the biomass fuel composition, moisture content, particle size and shape. The net calorific value as a high heating value calculated by elemental composition was obtained from a measurement of bomb calorimeter. The net calorific value of assorted wood pellets was higher than 1.2 times that of rice husk pellets because of high lignin content.
in assorted wood compared to that in rice husk. It was noticed that the assorted wood lignin content was higher compared with rice husk lignin content. Mechanical durability of rice husk pellets was less than that of assorted wood pellets due to the chemical composition of biomass fuel especially lignin content in lignocellulosic biomass. This is because lignin melts as biomass is heated during pelletization process and becomes soft with the aid of moisture content and exhibits thermosetting properties in solid biofuel. The physicomechanical properties of produced rice husk pellets, and assorted wood pellets were compared with ISO 17225-6 standard for the herbaceous biomass and ISO 17225-2 standard for by products and residues from wood processing industry. It could be observed that the length, moisture content, bulk density, net calorific value, and mechanical durability of manufactured pellets were complied with those ISO standards.

4. Conclusions
This work discussed on the chemical composition, proximate and ultimate analysis of potential biomass such as rice husk, and assorted wood and physicomechanical properties produced pellets compared with ISO 17225-6 and ISO 17225-2 standards. The chemical composition of biomass especially lignin content was strongly influence on mechanical durability. The moisture contents of biomass were affected on both the mechanical durability and calorific value in biomass. The ash content was depended on the ash formation constituents in biomass fuel. The moisture content, bulk density, net calorific value, and mechanical durability of produced potential biomass pellets were fitted with those ISO standards.

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