Effect of Moisture Content on Combustion and Friability Characteristics of Biomass Waste Briquettes Made By Small Scale Producers in Tanzania

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Abstract: **Biomass energy in forms of wood and charcoal fuel are the only sources of energy for cooking and heating that can be accessed by most people in developing countries. The high demand of fuel has lead to the utilization of agro and forest wastes through briquetting processes which increase energy to volume ratio. In this study sawdust briquettes made by Mkombozi group in Lushoto Tanga were analyzed to evaluate the impact of moisture content on combustion and friability properties of briquettes. The methods used to conduct the analysis involved the Bomb Calorimeter test, Water Boiling test, Friability test and Moisture Content test. The tested briquettes were categorized into two groups which are high moisture content and low moisture content briquettes with average moisture content of 29% (wet basis) and 12% (wet basis), respectively. The Bomb Calorimeter test result showed that calorific value of dry briquette material is 15 MJ/kg. Friability test showed that the briquettes with high moisture content has Impact to Resistance Index (IRI) range from 55 to 71 while the IRI for briquettes with low moisture content was between 80 and 160. Combustion analysis showed that both groups of briquettes emit more CO than CO2. The CO emitted was between 150 to 300 ppm while CO_2 were less than 100 ppm. The study concluded that moisture content affects the friability and combustion properties of briquettes.**

Keywords: **Biomass briquettes, energy, moisture content, combustion, friability.**

1. INTRODUCTION

1.1 Background:

The global energy consumption is expected to continue to rise due to increase in population growth and economic activities in developing countries. Worldwide primary energy consumption in the end-use sectors was projected to grow by 0.5% per year from 2007 to 2030, with annual demand for renewable fuels also increasing. Biomass consumption would increase by 4.4% per year during 2007 - 2030 and is expected to make up 22% of total marketed renewable energy consumption by 2030, compared with 10% in 2007 (US Government, 2009). Population growth appears to have a significant impact on increase in energy consumption. Analysts have projected that most of sub-Saharan Africa energy consumption will be largely driven by population growth (especially biomass energy consumption which is mainly used at the household level for cooking).

Tanzania is among of sub Saharan African countries whose energy consumption increases due to population growth. In 1990 Tanzania had 25,993,000 people whose energy consumption was 713,840 TJ. Fig. 1 shows the relative trend of energy consumption in Tanzania from 1971 to 1999.

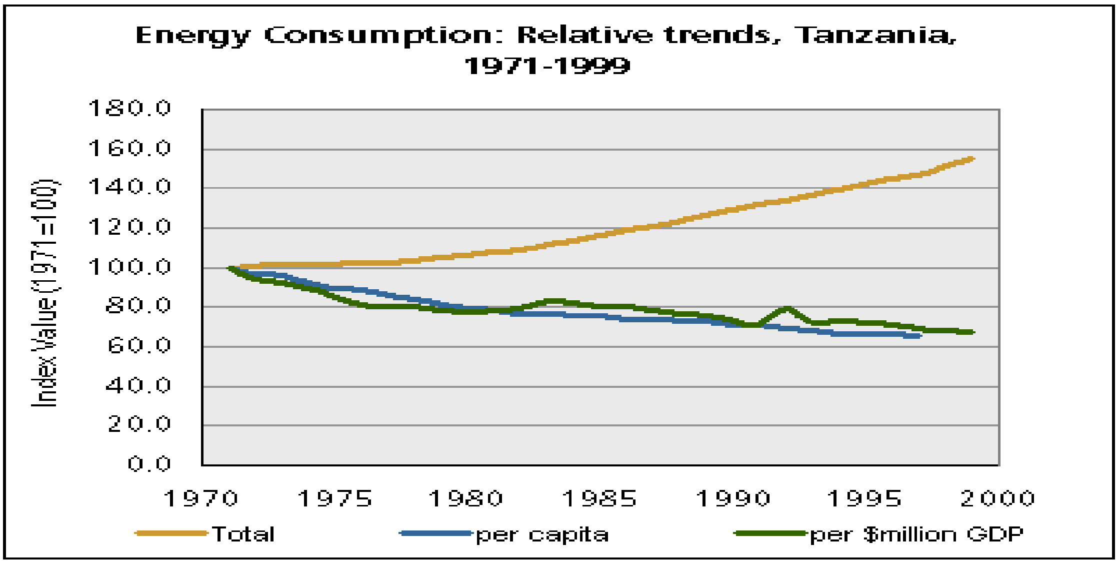

Fig. 1: Trend of Energy Consumption in Tanzania (Source: World Resource Institute, 2006)

From 2003 the estimated annual total energy consumption is more than 22 million ToE or 0.7 ToE per capita (IEA, 2003). The energy balance is characterized by biomass (mainly wood fuel and charcoal) use that accounts for about 90% of the total primary energy consumption. Commercial sources that are petroleum and electricity account for about 8% and about 1% respectively. Other sources including coal, solar and wind account for less than 1% of the total primary energy consumed. (Lema, 2007). Biomass fuel is the dominant source of energy in Tanzania for cooking and heating. Firewood and charcoal also supply the energy needs of numerous small-scale industries and business. Due to this practice Tanzania has experienced a loss of forest cover of more than 10.5 million ha between 1961 and 1998, this represents an annual loss of 0.73% of forest (MNRT, 2001), charcoal and firewood use alone contributing 70% of forest loss (E. Zahabu and R.E Malimbwi, 2001). The average wood fuel use per capita is about 1.5 m^3/annum/person or 1 ton of wood (Mnzava, 1991). This situation results in shortage of fuel for cooking, which causes women to walk for long distances to collect firewood daily.

The shortage of wood fuel has promoted the utilization of other resources of energy, such as biomass wastes. Tanzania generates plenty of biomass wastes per annum, for example, more than 15 million tonnes are generated every year from crop residues alone (Mhaiki and Mwenzengule, 2008). However, these biomass wastes currently are disposed either by burning or dumping, because they are light and not suitable for burning in conventional stoves. Renewable energy technologies such as briquetting have shown the potential of converting biomass wastes into usable energy sources. Briquetting technology increases energy per unit volume of biomass wastes through densification process, thus it can increase energy supply from biomass wastes and hence reduce competition on wood fuel sources. Despite a high emphasis of promoting the use efficient biomass conversion technologies such as briquetting in order to save resources; reduce rate of deforestation and land degradation; and minimizing threats on climate change, yet briquettes produced by local producers such as Mkombozi group in Lushoto-Tanga through hand operated machines are of poor quality. This study focused on investigating the effect of moisture content on the briquettes properties produced by small scale producers such as Mkombozi group.

2. MATERIAL AND METHOD

To achieve the objective of this study, a number of methods were considered in data collection and analysis.

2.1 Briquettes Storage:

Briquette samples made by Mkombozi group in Lushoto Tanga were dried and packed in sealed plastic bags to avoid moisture absorption and desorption. These samples were then transported to Dar es Salaam to the University of Dar es Salaam for testing and analysis. Upon reaching Dar es Salaam, briquettes were divided into two bundles. The first group consisted of briquettes that were taken out of the sealed bags, weighed and stored in a dry place to allow further drying until equilibrium moisture content (MC) was reached for four week. The second group composed of briquettes that were retained in their original condition in sealed bags.

2.2 Determining MC of Briquettes:

Moisture content (MC) is the amount of water in solid fuel (briquettes) which is expressed as the percentage by weight, of the dry or wet sample. For both groups of briquettes moisture content was measured. The MC of the sawdust briquettes was obtained using ASTM D 2016-74 methods. In term of wet basis, moisture content was analyzed by using eqn. (1);

$$MC_{wb} = \frac{W_w - W_d}{W_w} \times 100\% \quad [2.1]$$

And on dry basis, moisture content was analyzed by using eqn. (2.2);

$$MC_{db} = \frac{MC_{wb}}{100 - MC_{wb}} \times 100\% \quad [2.2]$$

2.3 Briquette Friability Test:

This is the measurement of the briquette's resistance to mechanical action which mainly happens during transportation and handling of briquettes. From each group of briquettes, three bundles which consisted of 5 briquettes each were exposed for friability measurements. The bundles of briquettes were placed 2 m above a concrete floor from which every bundle was dropped five times. The Impact to Resistance Index which is a measure for friability was calculated by using eqn. (2.3).

$$IRI = \frac{100 \times N}{n} \quad [2.3]$$

Where

IRI = Impact to Resistance Index

N = Number of drops

n = Total number of pieces after N drops

2.3 Water Boiling Test:

This test in connection with emission analysis was done particularly to analyze the combustion characteristics of briquettes. The following procedures were used in conducting the test;

Three bundles of briquettes from each group of briquettes were weighed before the test. The first bundle which contained briquettes that were exposed to ambient atmosphere in Dar es Salaam was placed in normal cooking stove. Two and a half litres of water at room temperature was taped in the pot. Wooden fixture with thermometer was kept at the centre, 5 cm from the bottom of pot. Fire was started and timer was switched on and starting time was recorded. The pot with the wooden fixture and thermometer was kept on the fire. When water reached the boiling point, the temperature was recorded and charcoal briquettes were removed from the stove and extinguished with sand. The extinguished charcoals were weighed; the unburned briquettes were weighed too and recorded. The weight of the pot with boiled water was also recorded. The procedure was repeated for the other bundle of briquettes. The important parameters to be analyzed from this test were;

2.3.1 Briquette consumed (f_{cm}):

This is the mass of briquette that was used to bring water to a boil.

$$f_{cm} = f_{ci} - f_{cf} \quad [2.5]$$

Where

f_{ci} = weight of briquette before the test

f_{cf} = weight of briquettes after the test

2.3.2 Equivalent Dry Briquettes Consumed (f_{cd}):

This is a calculation that adjusts the amount of briquettes that were burned in order to account for two factors: (1) the energy that was needed to remove the moisture in the briquettes and (2) the amount of chars remaining unburned

$$f_{cd} = f_{cm}[1-(1.12\times m)]-(1.5\times \Delta C_c) \quad [2.6]$$

Where;

ΔC_c = Amount of char after test

m = Mass briquettes used in test

2.3.3 Burning Rate (r_{cb}):

This is a measure of the rate of briquettes consumption while bringing water to a boil.

$$r_{cb} = \frac{f_{cd}}{t_{ci} - t_{cf}} \quad [2.7]$$

Where;

t_{ci} and t_{cf} time at start and finishing of the test respectively

2.4 Gas Emission Analysis:

The study analyzed the emission from the combustion of briquettes, and the main gas considered in analysis was CO because it is the most harmful to human health especially for indoor cooking. Before measurement of the gas, Testo Comsoft 3 Basic software for the gas analyzer machine was installed in the PC (Laptop) and the CO measurements were recorded after every 2 minutes.

2.5 Calorific Value of Briquette:

The energy value of sawdust briquettes was obtained by using a Bomb calorimeter. ASTM D 3172-5 standard was used to obtain the calorific value of the fuel. A Wagtech Gallenkamp Bomb calorimeter of model CAB101.ABC.C with S/No SG99/11/466 was used to measure the heat value of the fuel sample. Three tests were conducted and the Calorific value was determined.

3. RESULT AND DISCUSSION

3.1 Moisture Content of Briquette:

The moisture of sawdust briquettes on dry basis was determined by drying samples in an oven at 110°C until constant weight of the sample was reached. The briquettes exposed to ambient condition in Dar es Salaam recorded low percentage of moisture content, but briquettes which were sealed from Lushoto recorded higher moisture content. Fig. 2 shows the drying rate of sawdust briquettes.

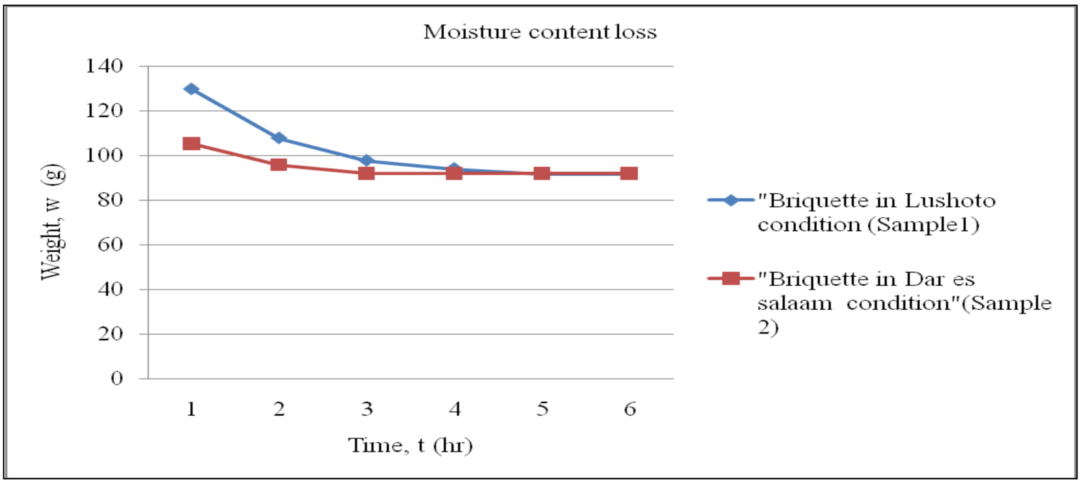

Fig. 2: Rate of Moisture Content Loss for Sawdust Briquettes

The graph shows an evidence that briquettes packed and sealed from Lushoto (referred to as sample 1) had higher moisture content to that were exposed to ambient temperature in Dar es Salaam (referred to as sample 2). The rate of weight loss in the drying process for sample 1 briquettes was also high as compared to sample 2. This implies that briquettes produced and packed by Mkombozi group are not well dried leading to high energy loss particularly in the combustion process. In this analysis (wet basis) briquettes from sample 1 had high MC of 29% and sample 2 had low MC of 12%.

3.2 Calorific Value Analysis:

Through the Bomb Calorimeter test, the Calorific values of the sawdust briquettes was obtained, and it varied between 13.5 MJ/kg to 16.1MJ/kg for the three samples that were tested. The average Calorific value of the saw dust briquettes was calculated to be 15 MJ/kg. Since the briquettes contain other materials such as waste paper as binding material, which have different energy value, the mean value from bomb test of the briquette sample is the average of energy of sawdust and other materials.

3.3 Resistance to Break:

The mean results of friability test are presented in Fig. 3. The briquettes with low MC had high Impact to Resistance Index compared to briquettes which had high MC.

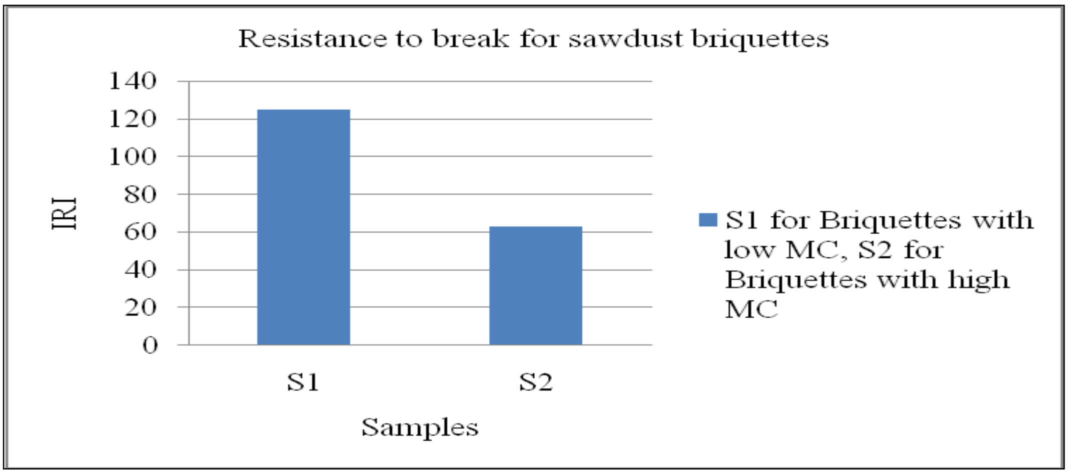

Fig. 3: Impact to Resistance Index (IRI) for Sawdust Briquettes of High and Low MC

IRI of briquettes with low MC ranges from 80 to 160 IRI while that of briquettes with high MC ranges from 55 to 71 IRI. IRI value of 50 is the minimum allowable impact resistance for fuel briquettes to be acceptable for transportation (Richards, 1990).

3.3 Water Boiling Analysis:

Water boiling test conducted in this study was for the purpose of determining the amount of the briquette fuel consumed and its burning rate under these two conditions. From Fig.4 shows the specific consumption of sawdust briquettes with low MC was 0.104 g of briquette/g of water, while for briquettes with high MC is 0.063 g of briquette/g of water).

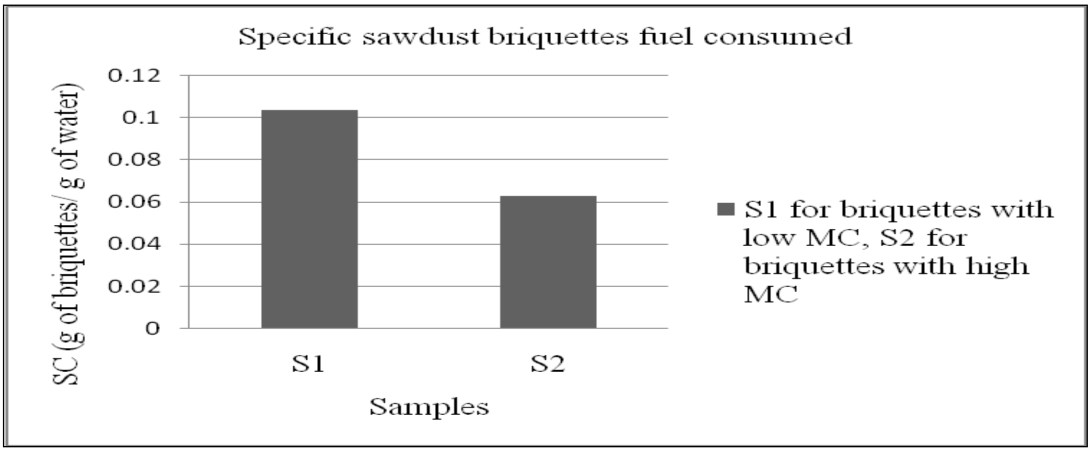

Fig. 4: Specific Sawdust Briquettes Fuel Consumption

From this graph it shows that sample of briquettes with low MC (12% MC wet basis) labelled S1 has high specific consumption than the briquettes labelled S2 which has high MC (29% MC wet basis). The briquettes with high MC burn slowly due to high moisture content and hence they have low values.

Fig.5 presents the burning rate of briquettes fuels with low and high MC. The briquettes with high MC have low burning rate compared to those with low MC. This is because some of the energy derived from burning of briquettes is used to drive away moisture from briquettes before undergoing combustion. Thus high moisture contents in briquettes reduce the potential energy values of briquettes.

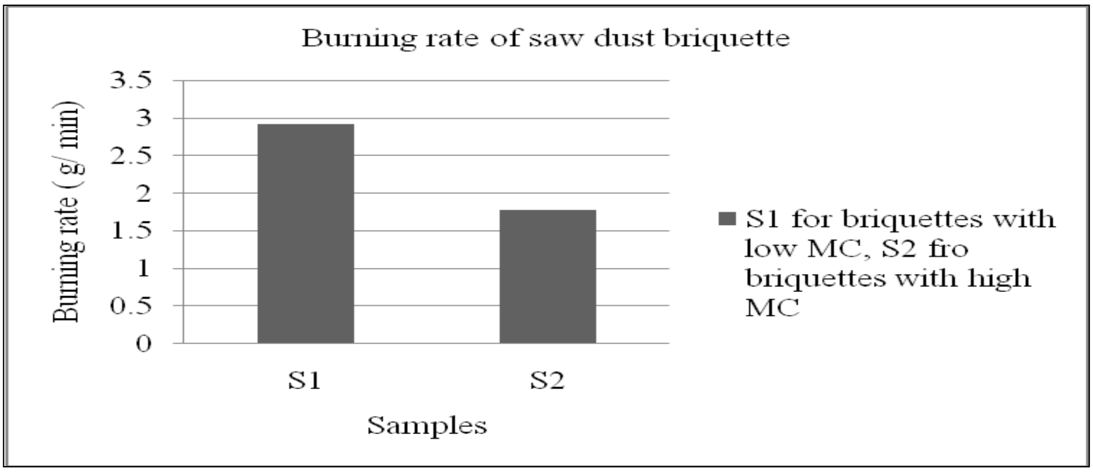

Fig.5: Burning Rate of Sawdust Briquette at Different Conditions

3.4: Emission Analysis:

Before conduction of combustion experiments the analyzer was allowed to record the existing ambient condition, and initially there was no exposure of CO gases. After firing the sawdust briquettes the analyzer recorded the gases emitted as presented in Fig.6. Initially the emissions were low but increased gradually. An abruptly increase was noted and finally decreased again. This indicates that at initial stage the volatiles combustion did not emit CO until char started to burn where CO increased. The graph shows more CO was emitted from briquettes with high MC.

On the other hand CO_2 emission as presented by Fig.6 was experienced to increase with time by both samples of briquettes, however briquettes with low MC emitted more CO_2 gases than briquette with high MC. The increase of CO_2 emission indicates that complete combustion is reached as the combustion of solid fuel pass through drying, pyrolysis and complete combustion.

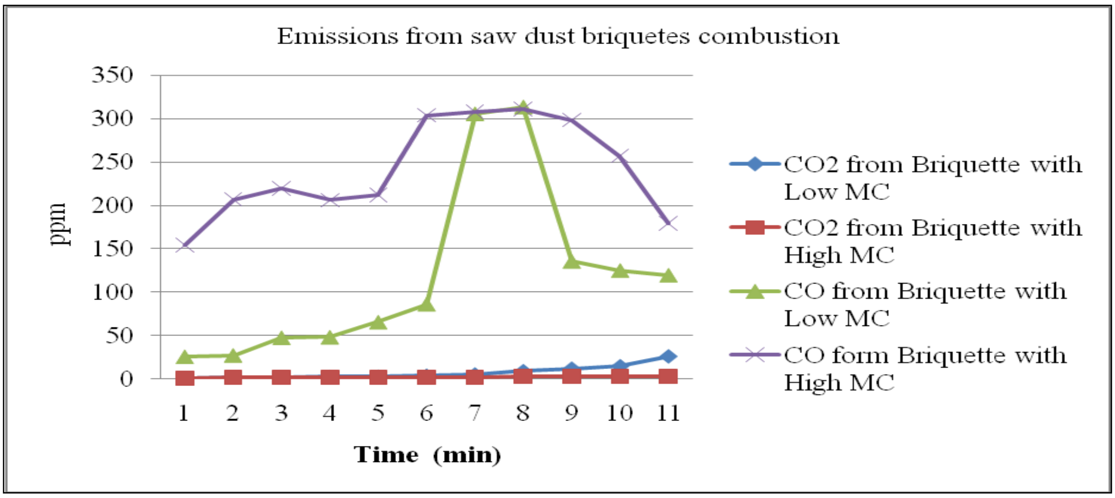

Fig.6: CO & CO_2 Gases from Sawdust Briquettes Burning

From figure 3.5 it is evident that burning of briquettes was not complete because the CO emissions are higher than that of the CO_2 in all the conditions of the sawdust briquettes, and this being facilitated by high moisture content of briquettes.

4. CONCLUSION

Combustion analysis and friability of briquettes were the main parameters that were taken into consideration when conducting this study. These properties are much affected by the moisture content (MC) in the fuel. Because of that the samples were prepared to represent high and low MC briquettes and the values were established and grouped as Low MC (12%MC wet basis) and High MC (29%MC wet basis). The briquettes at these two conditions (Low and High MC) were tested for their ability to resist breakage and abrasion, especially when the briquettes are transported for a long distance. In this test the briquettes showed good result, thus for the briquette with Low MC has a mean IRI of 70 and those with High Mc have average IRI of 55.

In combustion test the briquettes showed they are not appropriate especially for indoor cooking. High MC content in briquettes hinders good combustion of briquettes as it results to high CO emissions. This makes briquettes made from hand operated machines unfit for indoor applications. Thus, to make useful application of this renewable and alternative source of energy for cooking, the feedstock for briquettes should be well prepared that finer materials should be used with a good mixing ratio including carbonizing the feedstock for the purpose of reducing moisture content in the briquettes made. On the other hand briquette drying should be done on a tray to enable briquettes dry faster and on all sides.

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