PHYSICO-THERMAL CHARACTERIZATION OF BIOMASS MATERIALS OF DIFFERENT NATURE OF BRIQUETTES

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ABSTRACT

Biomass can be used efficiently by making biomass briquettes which may help resolving the problems related to handling, storage and transport. The present study was conducted in the Department of Structural and Environmental Engineering, University of Agriculture, Faisalabad, Pakistan during 2014 in order to check physical and thermal properties (density, durability, calorific value and percentage of ash contents) of different combinations of biomass materials such as sawdust + cotton sticks (A), sawdust + sunflower (B), sawdust + maize straw (C), sawdust + rice husk (D) and sawdust + garden waste (E) used for briquetting. The moisture content, compression ratio and particle size were taken as independent variables while durability, density, calorific value and ash content percentage were taken as dependent variables. Biomass briquettes were made for compression ratios (1:7, 1:8.5 and 1:10), particle size (6, 3 and 1 mm) and moisture content (12, 10 and 8% w.b.). The dwell time was 60 seconds. At each briquetting condition, three replications were used. The results showed that the best physico-thermal characteristics were attained at less than 10% moisture content, 1:10 compression ratio and 3mm particle size. The briquettes B and A recorded durability, density, calorific value and ash content were 90%, 1001kg/m^3, 19.44MJ/kg, 2.5% and 89.22%, 1000.11kg/m^3, 17.94MJ/kg and 7.3% respectively. The combination C recorded 18.92MJ/kg calorific value with 3.6% ash content.

KEYWORDS: Biomass; briquettes; densification; physico-thermal; characterization; Pakistan.

INTRODUCTION

Pakistan is presently facing serious energy crisis. As no proper steps have been taken previously to establish new ability for the production of essential energy sources the demand exceeds supply. The load-shedding has now become painful phenomenon due to frequent power shutdowns. Pakistan's per day electricity demand is about 32000 MW which is expected to increase

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upto 48843 MW per day by 2020. Currently, Pakistan has capacity to generate about 26000 MW per day with a shortfall of about 6000 MW per day. This shortfall is badly affecting industry, commerce and daily life of people (5).

In Pakistan non-scientific and conventional energy techniques need a shift to modern technology of bio-energy to overcome shortage of energy. There are many renewable energy sources that can be helpful to overcome the shortage of power generation. Biomass is one of them which can be used for power generation. Biomass is a source of renewable energy that was improved to surmount the shortage of energy sources in the upcoming situations because the supply is unlimited.

Biomass is an organic material, which is commonly generated from wood and diffused from homes, industry and agriculture. People are burning wood to heat their houses and cooking from ages. Being an agricultural country, Pakistan has potential to use biomass as source for energy (1). Pakistan depends mostly on conventional energy resources and no serious effort has been done for the use of renewable energy resources for generating electricity. Due to the dependence on fossil fuels, currently more than 60 percent of the foreign exchange is required for the import of energy (12). Currently, about 1000 briquetting machines are working in the country. In Bangladesh, locally made briquetting machines cost about 833 US $ (6).

In the modern era, energy is a key element for the sustainable development and prosperity of country. The total primary energy supply (TPES) of Pakistan was 62.6 million tons of oil equivalents (MTOE) in the financial year 2008-09 from resources such as oil, hydropower and nuclear power, coal, gas and liquefied petroleum gas (LPG) to 48.3 percent, 32.1 percent, 11.3 percent, 7.6 percent and 0.6 percent of the primary energy supply (2). Pakistan is an energy-deficient country with problems of energy, specially electricity. There was about 4000 MW power deficit in the country during 2013 which might be 8000 MW in the end of 2015. Problem will continue in future because national energy demand is increasing at an average annual rate of 5.67 percent (4). Due to high cost of fossil fuels, decline in primary energy supply was observed 0.6 percent higher in 2009 from 2008 (2). Import of fossil fuels especially oil has put much stress on the national economy. Pakistan is trying to increase domestic energy supply for which renewable energy has been identified as an important target area. Therefore, it is crucial for the country to devise energy strategy to increase the share of sustainable and local energy resources. Renewable raw materials offer many advantages for the environment in addition to the provision of electricity (4, 7).

Biomass is a renewable energy source because it is available in abundant quantity in Pakistan. A huge amount of waste is also available (3). Most biomass materials contain high amount of water and less density making them unfit for direct usage. Conversion of biomass material into briquettes is the only solution that can facilitate to increase the volumetric and calorific value and decrease costs of transportation. Two dissimilar types of technologies of densification are presently in use. The first is pyrolizing technology for biomass mixed with binder and turned into biomass briquettes by casting action and pressing. The second technology is called direct extrusion type, in which the biomass is kept for drying and compacted directly by pressure and heat. Currently two major technologies of high pressure including piston press and screw extrusion are being used for the purpose of briquetting. The briquettes produced by the piston press technology are completely solid but on the other hand screw press briquettes have a hole which provides improved combustion characteristics due to a more specific area. Briquettes produced by screw press technology are also homogeneous and don't collapse easily. Due to the high combustion rate these can be used in boilers instead of coal. Keeping in view, a study was designed to characterize biomass of various compositions for physical and chemical properties to observe whether the biomass materials can be used for briquetting purpose by mixing them or not.

MATERIALS AND METHODS

This study was conducted in the Department of Structural and Environmental Engineering, University of Agriculture, Faisalabad, Pakistan during 2014 with objective to control and analyze the physico-thermal properties of biomass to be used as briquettes. The residues of different crops were collected as a raw material from different areas of district Faisalabad. The residue of maize, cotton, sunflower, rice, garden waste and sawdust were collected. The mentioned biomass materials were shredded using hammer mill. Three particle sizes (6, 3 and 1 mm) were collected by changing the sieve of hammer mill. A self-fabricated piston press compaction model was used to make briquettes at different compression ratios. The compaction apparatus was used to make a single compaction with one stroke of the plunger from ground straw sample. Biomass briquettes were made for the following factorial combination of conditions: (i) compression ratios 1:7, 1:8.5 and 1:10 (ii) particle sizes 6, 3 and 1 mm and (iii) moisture contents 12, 10 and 20 percent (w.b.) with 60 seconds dwell time. At each briquetting condition, three briquettes (i.e. 3 replications) were made. In this study, no binders (additives) were used for briquetting.

The combinations made by mixing the biomass material of 1:1 ratio by weight were as under:

A ——— Sawdust : cotton sticks
B ——— Sawdust : sunflower
C ——— Sawdust : maize straw
D ——— Sawdust : rice husk
E ——— Sawdust : garden waste

Analysis of physico-thermal properties

Density: Density is an indicator of savings in storage and transportation space and cost of briquettes. The density of compacted blocks was calculated using equation given below. The volume was determined by the cross sectional area and variable thickness of the briquettes.

$$Density\ (kg/m^3) = mass/volume$$

Durability: Durability is the ability of densified briquette to remain intact in the procedure of handling. Durability was measured with drop resistant test. Briquette was dropped two times from the height of 1.8m. The weight retained as percentage of initial weight was taken as briquette durability.

Ash content (%): Ash contents were also determined through Muffle Furnace 1400 using the formula;

$$ASH = \frac{W_D - W_A}{W_B - W_A} \times 100$$

Where;

ASH	=	Ash contents (%)
W_A	=	Weight of empty & previously ignited capsule (g)
W_B	=	Weight of capsule + air dried sample (g)
W_D	=	Weight of capsule + residue after ignition (g)

Calorific value: The calorific value of different fuels was measured with the help of bomb calorimeter. The higher heating value or calorific value was then calculated by the following formula that is used in bomb calorimeter method.

$$CV\ (MJ/kg) = \frac{\Delta T \times 2426 - (2.3 \times \Delta L + \Delta V}{W} - 464$$

Where;

CV = Calorific value (kcal/kg)
ΔT = Change in temperature (^{o}C)
ΔL = Length of wire used (cm)
ΔV = Volume of Na_2CO_3 used (ml)
W = Weight of sample + capsule

The kcal/kg was converted into kJ/kg by following conversion factor:

1 kcal/kg = 4.184 kJ/kg

RESULTS AND DISCUSSION

There are some properties of biomass which are necessary to be considered before the densification of biomass (density, durability, calorific value and ash content) for better handling, storage transport and burning purpose. The properties of biomass also depend upon some other parameters of biomass such as particle size, compression ratio and moisture content. By increasing compression ratio the volume of biomass can be reduced and thus it will result in increased density in briquette form.

The results showed that the briquetting should be performed at < 10% moisture content, 1:10 of compression ratio and with a particle size of < 5 mm, which can be obtained using a hammer mill screen. At these parameters best quality of biomass briquettes can be obtained without using any binder in briquetting mechanism.

This study demonstrated that density of the briquettes were dependent on moisture content, compression ratio and particle size Fig 1. As the moisture content decreased from 12 percent to 8 percent the decreasing pattern was observed in density of briquettes of all combinations. The densities of all combination briquettes increased with the increase in compression ratio because the increase in compression ratio decreased the volume of briquettes. Thus, with the decrease in volume, density was increased. At the end 3mm particles size, briquettes had a high density compared with other two particle sizes.

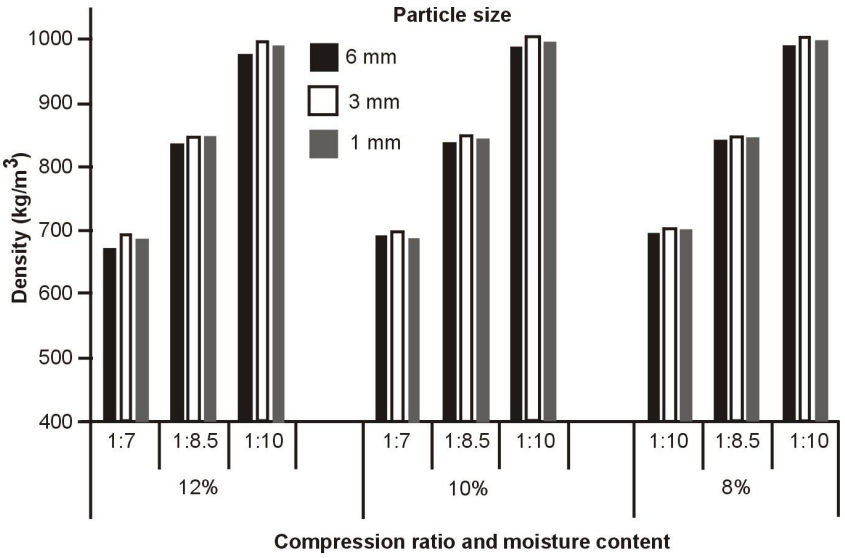


Fig. 1. Effect of compression ratio, moisture content and particle size on density.

At the earlier stage of study it was observed that for biomass as energy purpose the major limitation is its low density in lose form, typically ranging from 60-80kg/m^3 for agricultural straws and grasses and 200-400 kg/m^3 for woody biomass like wood chips (10). Previously it was reported that the densities of compacted biomass briquettes of individual biomass materials varied from 542-794 kg/m^3 (9). According to the present research (Fig. 2) the higher densities of mixed biomass materials (ranging 992-1001 kg/m^3) showed that mixed biomass material can be used as these briquettes had higher density values as compared to previous findings.

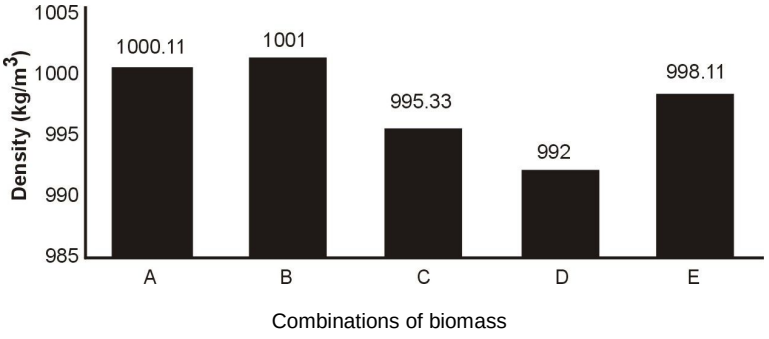


Fig. 2. Densities of all combinations.

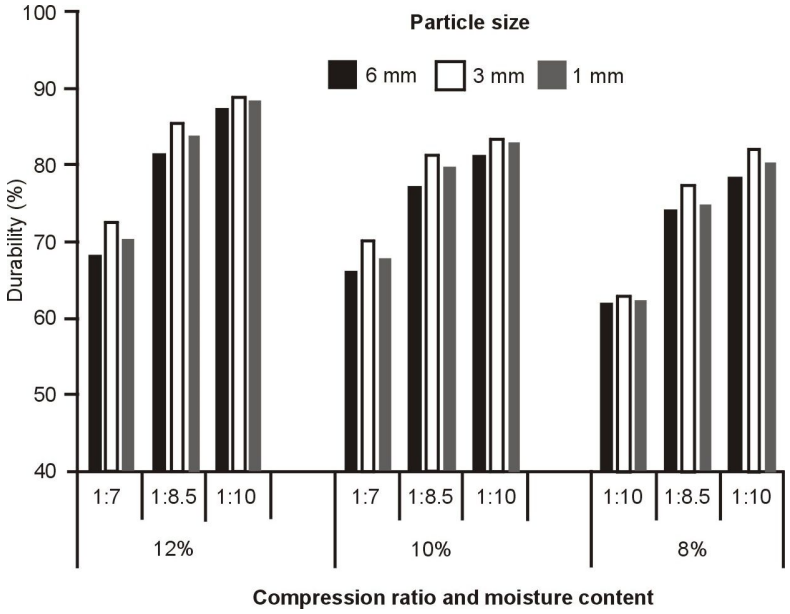


Fig. 3. Effect of compression ratio, moisture content and particle size on density.

The durability was determined by drop resistance test. It was observed that with the decrease in moisture content from 12 percent to 8 percent the durability was also decreased (Fig. 3). At 12 percent moisture content, water present in biomass material acted as a binder and in this way at 12 percent moisture content durability was high. Durability was also increased by increasing compression ratio from 1:7 to 1:10 and 3mm particle size was best for high durability of all combinations of briquettes.

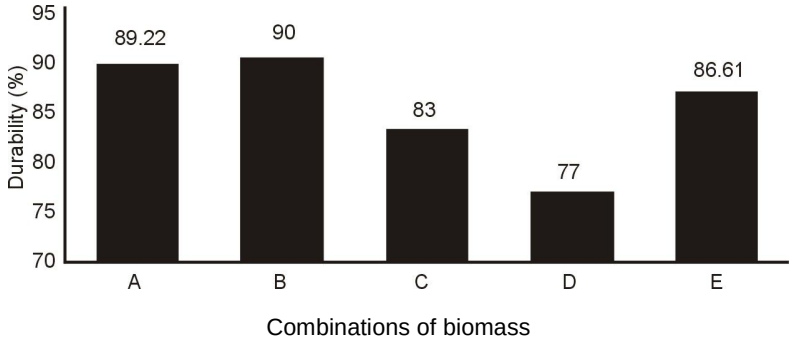


Fig. 4. Durability of all combinations.

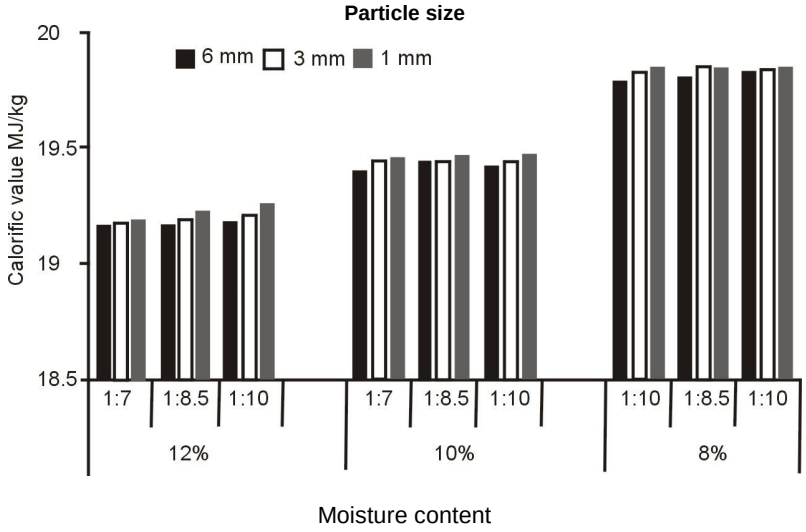


Fig . 5. Effect of moisture content on calorific value.

Individual biomass material for briquetting purpose was used in the past and the durability of briquettes was 87 percent (12). Now as per present results of durabilities of different combinations shown in (Fig. 4) ranged from 86-90 percent showed that these combinations of biomass can be used for briquetting purpose.

In case of determining calorific values the effects of compression ratio and particle size was neglected because calorific value was determined by bomb calorimeter and sample was put into the capsule of bomb calorimeter in grinded form. Only moisture content was the single factor responsible for the increase or decrease in calorific value of biomass briquettes. The decrease in moisture content from 12 percent to 8 percent caused increase in calorific values (Fig. 6). The calorific values of all combinations are shown in Fig. 6. According to previous study the calorific values of wood, sawdust, rice husk and dung were 15, 14.99, 14.77 and 12 MJ/kg, respectively (13). The present study showed that higher calorific values from 17-19.5 MJ/kg could be achieved from the combinations of biomass materials.

Ash contents were also determined in powder (ground) form. So only moisture content affected the ash content and other two parameters such as particle size and compression ratio were neglected. As the moisture content decreased from 10 percent to 8 percent, the ash content also decreased

(Fig. 7). The previous study showed that the ash content of cotton, rice husk and maize straw were 15.67 percent, 18.67 and 16.4 percent, respectively (14). It is clear from the present study that the ash content of briquettes of cotton, rice and maize straw by mixing with sawdust was reduced up to 7.3 percent, 10.6 percent and 3.6 percent, respectively. When the ash content is decreased the high calorific values can be obtained which implies that these combinations can be used for making efficient biomass briquettes.

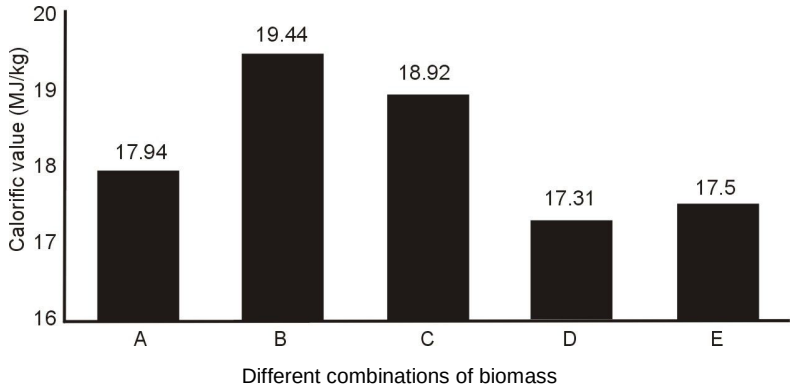


Fig . 6. Calorific values of all combinations.

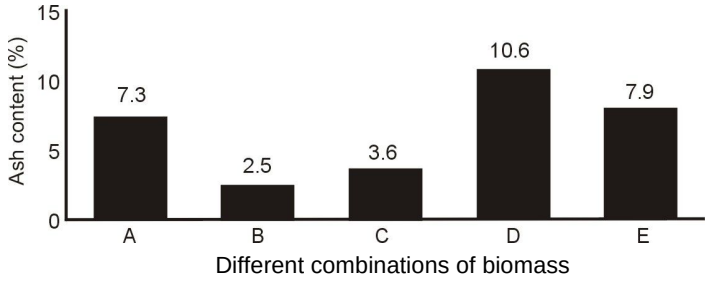


Fig. 7. Ash content of combinations.

CONCLUSION

It can be concluded from the results of this study that sawdust + cotton and sawdust + sunflower had higher values of density, durability and calorific value and less ash contents than other combinations. These findings imply that such biomass material could be used for the briquetting purpose without using any kind of binding material. By making briquettes many problems related to handling, storage, transport and burning will be reduced to a large extent. These biomass materials can be compacted at 1:10 compression

level, less than 10 percent moisture content and 3mm particle size for good quality briquettes which can be easily used in boilers as a fuel.

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