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Analysis and Test of Biomass Briquette and Stoves

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Abstract

Biomass such as agricultural and forestry residues are important resources for energy in Nepal. This biomass can be converted into densified soild biofuel by briquetting fuel technology which can address handling, transportation, and storage problems. In addition, it helps to increase a number of applications and enhance its utilization efficiency. The purpose of this study is to quantify the physical and chemical properties of different biomass, such as sawdust, banana stem, rice straw, etc. and combustion in order to investigate clear options. Additionally, it helps to provide the efficiency of stoves available at Nepal Academy of Science and Technology (NAST) laboratory. Among the feedstock tested, *Mikania micrantha* char had highest fixed carbon of 45.92% which clearly shows that it is a good source for biomass briquetting. Out of four stoves tested, Baked Ceramic 4 BHB Stoves had highest efficiency of 33.4% with Banmara briquettes. The study also showed reduced emission of harmful gases ultimately reducing the indoor air pollution. Thus, with the proper densification these fuels can be used as a substitute for the traditional fuels in domestic as well as industrial application in furnaces, boilers and kilns.

Key words: briquetting, fuelwood, improved cookstoves, indoor air pollution

Introduction

Energy is critically important in development, economic growth, national and regional environmental protection. The efficient production and use of energy in an environmentally sound way is essential to tackle these concerns and lead to sustainable development based on equity, empowerment, environmental harmony and economic efficiency. The overall energy consumption of Nepal is largely dominated by the use of traditional fuels (87.0%) such as fuelwood (77.7%), agriculture residue (3.7%) and animal dung (5.7%) (WECS 2010). The use of this traditional fuel for household (HH) cooking and heating in poorly ventilated kitchens cause indoor air pollution (IPA). In 2002, IAP was responsible for the death of 7,500 people in Nepal (WHO 2007). Also the social cost of collection of fuelwood is heavy. Women and children had to spend 2-3 hrs a day in the collection of fuelwood (K.C. *et al*. 2011). Hence, it is important to direct activities to address these problems by providing alternatives and improving the fuels characteristics as well as curtailing harmful emission.

Other major consumers of fuelwood, biomass, etc in Nepal are the industrial boilers, furnace and kilns (World Bank/UNDP 1993). These furnace, kilns and boilers use a variety of fuels ranging from fuelwood, coal, agricultural biomass to even old automobile tires. As there are more than 150 brick kilns operating in Kathmandu valley alone, they are major sources of pollution (Raut 2003).

The uses of these fuels not only lead to deforestation but also to environmental pollution and climatic changes. Smoke, Sulfur dioxide and nitrogen oxides are the major pollutants generated from these fuels (Luo *et al*. 1999). In search for alternatives to these pollutants Nepal has introduced several alternatives energy sources such as biogas, micro-hydro, kerosene, liquefied petroleum gas (LPG), improved cookstove (ICS), solar/wind technologies, briquettes, etc. Among these alternatives, briquettes based on agriculture residues and forest residues could be an alternative to fuelwood for cooking and other purposes (WECS 2010). One of the objectives of this research is to reduce the harmful emission through the introduction of briquettes. In addition, this study tries to analyze the physical and chemical properties of briquettes.

Methodology

Different biomass briquette and samples were collected and tested in the laboratory of NAST. Proximate analysis (moisture content, ash content, volatile matter content, and fixed carbon content) was carried out according to JIS M 8813 and calorific values of the samples were determined with Toshniwal Digital Bomb calorimeter (Model CC01/M2A). The efficiency of the sample/stove was calculated with standard water boiling test (WBT). Weight of fuel sample burned was measured by weighing the briquette on a balance. The efficiency of stove (η) was calculated by employing following formula:

$$\eta = \frac{M_1 \times C_{fw} \times \Delta T + M_{evap} \times L_f}{M_f \times H_f}$$

Where,

M_1	Initial weight of water	(Kg)
C_{fw}	Specific heat of water	(KJ/Kg/°C)
ΔT	Rise in temperature of water	(°C)
M_{evap}	Mass of water evaporated	(Kg)
L_f	Latent heat of evaporation of water (2250 KJ/Kg at 100°C and 10^5 Pa)	(KJ/Kg)
M_f	Mass of fuel burned	(Kg)
H_f	Calorific value of fuel	(KJ/Kg)

The smoke numbers of different fuels were measured using Bacharach scale to evaluate the smoke emission of different fuels. Pump with a filter paper was placed over the stove to suck the smoke emission. The spot created on the filter paper after suction of the emission was compared with the standard scale, which begins from 0 to 9 to evaluate the smoke density/emissions. The greater the smoke numbers, the higher would be the smoke emissions. For the breaking strength a tablet of 3mm thickness and ~ 25mm diameter were prepared from the biomass sample. These tablets were tested in a machine to determine the spring back ration.

Result and Discussion

Proximate analysis

The proximate analysis involves the use of simple tests, focused on estimating the main constituents of biomass which have a direct influence on the combustion characteristics, i.e. the moisture content of a biomass, the amount of volatiles, fixed carbon (char) and the amount of ash. For instance, the contribution of flaming and glowing combustion in biomass combustion process depends on the proportion of volatile matter and fixed carbon which together with the moisture content of biomass have a strong influence on the calorific value (RWEDP 1993). The results of proximate analysis are shown in Table 1.

Table 1. Proximate analysis of some biomass sample

S.N	Name of sample	MC (%)	VMC (%)	AC (%)	FC (%)
1	Coal (Hetauda, Nepal)	14.671	17.092	28.207	40.030
2	Low grade coal (Dang, Nepal)	1.263	62.055	13.640	23.042
3	*Alnus nepalensis* (Utis) saw dust,	10.48	68.93	1.05	19.54
4	*Mikania micrantha* char	3.448	31.464	19.12	45.921
5	*Eupatorium adenophorum*	9.22	73.62	1.89	15.27
6	Water hycinth	14.13	76.06	6.16	3.65
7	Pine needles (Tukuche)	13.210	64.877	3.757	18.156
8	BHB (Department store)	5.266	11.488	61.429	21.818
9	Wheat straw	9.21	73.28	4.21	13.30
10	Coffee husk	7.027	76.241	0.978	16.254
11	*Lantana camera*	12.12	66.99	4.29	16.58
12	Maize stalk	10.42	68.13	4.41	17.02
13	Rice straw (Khumaltar)	18.05	53.03	16.25	12.67
14	Banana stem	*35.95*	36.21	10.43	17.38
15	Rwanda peat char (Grinded)	6.218	12.959	46.447	34.376

Note: MC – Moisture content, VMC – Volatile matter content, AC – Ash content, FC – Fixed carbon

From the results of proximate analysis, out of 15 different laboratory samples, 13 had the moisture content within the limit of 15% recommended by Wilaipon (2008) for the briquetting of agro-residues. Whereas, rice straw (18.05%) and banana stems (35.95%) had more moisture content compared to other samples. According to Eriksson and Prior (1990), some materials with up to 20% moisture content can be classified in a piston press. He further added that moisture content above 10% might lead to excess steam production which can lead to steam explosion. The differences in material moisture content can cause higher variation in energy requirement than those between materials. Among these tested samples, *M. micrantha* char (45.921%) and coal from Hetauda, Nepal (40.0%) had high carbon content compared to others. According to the report published by FAO 1985, fixed carbon content for domestic and industrial purpose can range from 50% to 95%. Erlinda and Dionco-Adetayo (2001) explained that the charcoal for briquetting from high temperature will be higher in fixed carbon than the charcoal produced at lower temperature. Thus, we can say that Mikania char and Hetauda coal are good for bee-hive briquettes.

Calorific value

Another most important characteristics of a fuel is its calorific value, that is the amount of energy per kg it gives off when burnt. The calorific value can thus be used to calculate the competitiveness of a processed fuel in a given market situation. Some of the samples tested in the lab are shown in the Table 2 with some of their photographs.

Table 2. Calorific value of different samples

Water equivalent - 2540.264 Cal./ºC

S.N	Test date	Name of sample	Calorific value (kJ/kg)
1	07 January, 2011	CRUDE OIL (BIODISEL), IOE	38621.49
2	07 January, 2011	PLASTIC	45867.14
3	13 January, 2011	BIODISEL (10%) – B10	47756.69
4	06 January, 2011	IOE, TORRIFIED SAMPLE	23912.03
5	06 January, 2011	RAMCHE COAL 1	8186.37
6	07 January, 2011	AJIMARA COAL	25054.79
7	23 December, 2010	WOOD	22648.21
8	23 December, 2010	COAL	11472.75
9	23 December, 2010	BENZOIC ACID	10635.57
10	13 January, 2011	Briquette sample from NEC	4973.36

Fig.1. Some of the samples tested in a laboratory to find out calorific values

The higher heating value calculated for fuel samples was 47756.69 kJ/kg for Biodisel (B10) and lowest for briquette sample from Nepal Engineering College (4973.36kJ/kg). These energy values are sufficient enough to produce heat required for household cooking and small scale industrial cottage applications. These were also compared well with most biomass energy. For examples, groundnut shell briquette- 12,600 kJ/kg (Musa 2007), cowpea- 14,372.93 kJ/kg, and soybeans-12,953 kJ/kg (Enweremadu *et al*. 2004).

Efficiency of stoves

Water boiling test (WBT) was intended to help stove designers to measure how efficiently a stove was used to heat water in a cooking pot. The thermal efficiency of the SCORE stove (Fig.2) was found to be 15.88%. The low efficiency of the stove may be due to the material used i.e. cement. In addition, there was no open passage for the air to flow making the inefficient combustion of fuel. From bacharach smoke index test, the emission from the stove was found to be bad. There was one drawback of this stove that there was no ash remover so it was difficult to continue the burning period for longer period of time. During another study, Madhukar stove (Fig. 3) was found to have thermal efficiency of 25% with the operation of a fan. The special feature of this stove was that there was external air supply to burn the fuel. The emission from the stove was found to be at satisfactory level. The major drawback of this stove was that there was no ash remover so it was difficult to continue the experiment for long time. Also after, fuel wood changes to ash, it may enter into the cooking vessel because of air supply.

In another study carried out in the laboratory, top lit up draft (TLUD) gasifier stove (Fig. 4) showed the efficiency of 15.47% when wood was used as fuel material. This low efficiency may be due to design of a stove. Thus, modification and improvements were necessary for chimney, insulation and air supply system so that its efficiency can be increased. For testing multiple BHB, Ceramic 4 beehive briquette stove (Fig. 5) was used. During testing of these stoves it was observed that the stoves developed cracks getting heated from BHB as they were made from locally available clay. Again, due to its size, it was not possible to transfer conveniently avoiding the damage of stove. To address these problems, baked ceramic 4 BHB stoves was fabricated and tested in the laboratory. From the test, it was observed that the total burning time using 4 BHBs was more than two and half hours with the efficiency of 33.4% using banmara BHB.

Fig. 2. Score Stove

Fig. 3. Madhukar stove

Fig.4. Top lit up draft gasifier stove

Fig. 5. Baked ceramic 4 BHB stoves

However, stove consumers neither usefully compare the heat outputs of stoves nor their efficiency. Because it depends on different factors like how open the air vents were during the test or how often the stove was refueled.

Breaking strength

Breaking strength evaluates the stability and strength of briquette. It also shows the force required to break the prepared briquette. Ultimately, it helps by giving the information for proper handling and transportation of the briquettes to long distance. Table 3 gives the idea about the strength of the briquettes made from *M. micrantha* char.

From table, we observed that breaking strength increases with the increase in the briquette pressure provided in making the tablet. So, if we make briquette at high pressure then the strength of the briquettes were higher and they were stronger and stable too. However, with increase in briquetting pressure, the cost of briquetting increases very much.

Table 3. Breaking strength of sample

S.N	Biomass	Pressure (Mpa) to make tablet	Breaking strength
1	*Mikania micrantha*	5	2.41 Newton
2	*Mikania micrantha*	10	3.56 Newton
3	*Mikania micrantha*	15	4.05 Newton
4	*Mikania micrantha*	20	4.70 Newton

Conclusion

Briquettes were produced from variety of feedstock to compare their physical and chemical properties. The physico-mechanical characteristics of biomass raw materials showed the biobriquettes have better combustion with lower amount of smoke emission. The study confirms that medium size feedstock with low moisture content are more efficient compare to other. Efficiency of stoves show 4 ceramic BHB as better compared to others with banmara briquettes. However, comparing efficiency of stoves with each other depend on refueling periods and with the air vents open to varying degrees. Thus, the end users do not really know exact efficiency until the testing is done in specific conditions. The overall study recommends biobriquettes as an alternative fuel as it has lower amount of smoke emission, higher calorific values and ability to burn longer with stable and uniform temperature.

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