Physico-Chemical Characteristics and Market Potential of Sawdust Charcoal Briquette

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ABSTRACT

In view of soaring prices of petroleum products on the world market and concerns over the negative impact of deforestation on the environment, briquettes are a better replacement to LPG, kerosene, firewood and charcoal as energy source for heating, cooking and other industrial applications in both urban and rural centres. This study therefore sought to assess the physico-chemical properties of charcoal briquettes produced in Ghana. It also sought to establish demand for and willingness of potential users to substitute charcoal and firewood with a 'Grade B' charcoal briquette. The study employed a two tie approach (laboratory test and interviews using questionnaires). The laboratory experiment sought to determine the physico-chemical characteristics of the briquettes. Data on potential users' acceptability and willingness to use the briquettes were collected from 60 respondent using self-completion questionnaires. Results of physico-chemical assessment of the briquettes were as follows: length (75mm - 120mm), moisture content (5.7% dry basis), density (1.1g/cm^3), ash content (2.6%), fixed carbon (20.7%), volatile matter (71%) and calorific value (4820Kcal/kg). Response to the questionnaire gave the following observations: ease to ignite (97% responded yes), long burning time (78% responded yes), heat output (76% responded high). Moreover, all the respondents indicated that, the briquettes were sparkless, smokeless and have low ash content. Finally, 93% of the respondents indicated their willingness to use the briquettes. Based on the findings, the study concluded that there is indeed future and market potential for the use of biomass briquettes in the study area.

Keywords: Sawdust charcoal briquettes, physico-chemical characteristics, demand and potential user's acceptability

Introduction

As a result of growing worldwide concern regarding environmental impacts – particularly climate change – from the use of fossil fuels coupled with the volatile fossil fuel market and, the need for an independent energy supply to sustain economic development, there is currently a great deal of interest in renewable energy in general and biomass energy in particular. Biomass is one of the most common and easily accessible renewable energy resources and represents a great opportunity as a feedstock for bioenergy (McKendry, 2002). A wide range of biomass resources- crop residues (corn stover, rice husk etc), wood wastes from forestry and industry, residues from food and paper industries, municipal solid wastes (MSW) and dedicated energy crops such as short-rotation perennials- can be utilised to generate electricity, heat, combined heat and power, and other forms of bioenergy.

Traditionally, energy in the form of firewood, twigs and charcoal has been the major source of renewable energy for many developing countries (Emerhi, 2011). In Ghana, it is estimated that, about 90% of bulk woodfuels is obtained directly from the natural forest while the remaining 10% is from wood waste (logging and sawmill residues) and planted forests (EC, 2008). Woodfuels – firewood and charcoal – forms the most dominant source of energy in Ghana and is used significantly in both rural and urban communities for cooking and many other heating applications. According to KITE (1999), about 70% of the total national energy consumption is accounted for by biomass in either direct or processed form, a trend that has continued for the last decade (Fig. 1). The over reliance on forest wood in Ghana mainly for charcoal production, firewood and furniture making has resulted in the depletion of forest reserves at a faster rate – estimated at 3% per year (Trossero, 2002). A similar scenario according to Emerhi (2011), in other sub-Saharan countries has resulted in shortage of fuel wood which has led to the depletion of over 75% of the total forest cover and thus leading to environmental crises. As rightly noted by Stout and Best (2001), a transition to a sustainable energy system is urgently needed for developing countries.

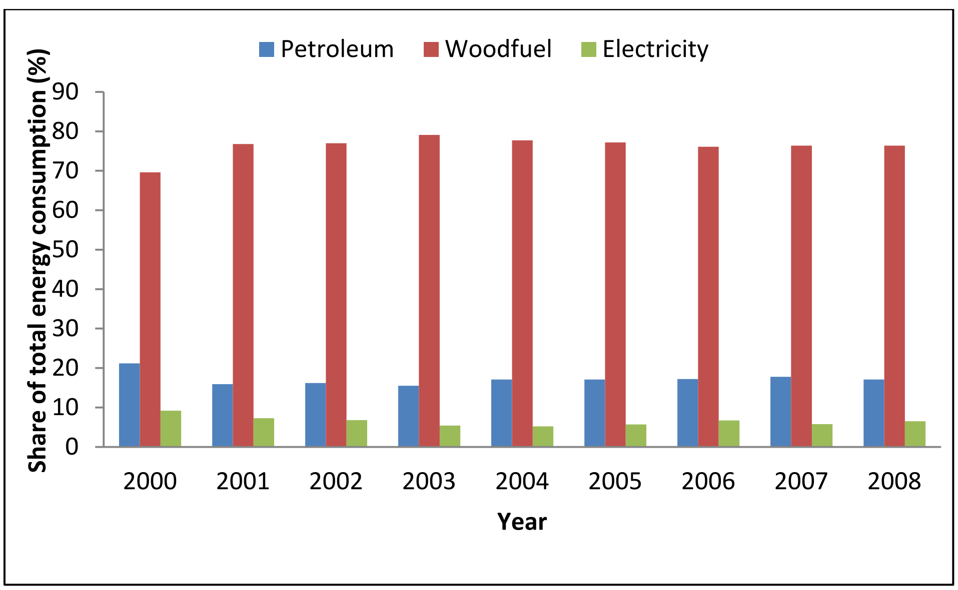

Figure 1: Trend of energy consumption by type of fuel

Among the several kinds of biomass resources, agricultural residues - sawdust, rice husk, corn stover, cotton stalk, groundnut husk etc - have become one of the most promising choices as cooking fuels due to its availability in substantial quantities as waste annually. However, the utilisation of these biomass residues in their natural form as fuel is difficult because of their very low bulk density, low heat release and the excessive amounts of smoke they generate. All of these characteristics make them difficult to handle, store, transport, and utilize in their raw form. One of the ways of improving the thermal value of such biomass is the application of briquetting technology (Wilaipon, 2007). This involves the densification of loose biomass to produce fuel briquette which has better handling characteristics and enhanced volumetric calorific value (Oladeji, 2010). According to Styles *et al*. (2008), briquettes are a key technology for increasing biomass use in both electricity and heat production.

The production of briquettes from sawdust exemplifies the potential of appropriate technology for wood waist utilization. If produced at low cost and made conveniently accessible to consumers, briquettes could serve as complement to firewood and charcoal for domestic cooking and agro-industrial operations. Besides, briquettes have advantages over fuel wood in terms of greater heat intensity, cleanliness, convenience in use, and relatively smaller space requirement for storage (Singh and Singh, 1982; Wamukonya and Jenkins, 1995; Yaman *et al*., 2000; Olorunnisola, 2004). Successful briquette operations are found mostly in developed countries. An example is the industry based on carbonization of sawdust and bark in the southern USA. However, briquetting operations are not successful in developing countries like Ghana and other African countries. This is mostly due to the high cost of production, lack of awareness on its sustainability, availability of market and poor packaging and distribution systems for the product (Emerhi 2011).

Commercial production of sawdust briquette was introduced in Ghana in 1984. Though the briquettes had high prospect as an alternative to firewood and charcoal, it could not be promoted widely especially with the household sector due to operational and marketing challenges. Notably, Oladeji (2010), also reported that, if biomass or agro-waste briquettes are to be used efficiently and rationally as fuel, they must be characterized by determining it parameters such as the moisture content, ash content, density, volatile matter, and heating value among others. Therefore, this study assessed the physico-chemical properties of charcoal briquettes produced in Ghana. It also sought to assess the market potential of charcoal briquettes in the study area to establish demand for and also the willingness of potential users to substitute charcoal and firewood with the sawdust charcoal briquette.

Materials and Methods

Raw material

The samples of sawdust charcoal briquette used for the study were obtained from a briquette producing company in the Kumasi Metropolis. In all, 600kg of briquettes were acquired for the study. The production of briquette at the company is by the extrusion process through the use of screw press briquetting machine at die pressure range of 100-200MPa with no additives such as starch binder. The briquette in (Fig. 2) is carbonised and square sized (0.035m × 0.035m) with a concentric hole diameter of 0.01m.

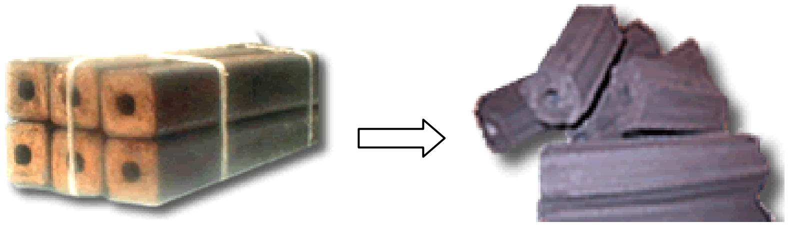

Figure 2: Sample of carbonised sawdust charcoal briquette

Determination of physico-chemical properties of sawdust charcoal briquette

The calorific value, density, proximate and ultimate analysis of the sawdust charcoal briquette was determined prior to distribution to sampled potential users. According to Chaney (2010), proximate analysis is a standardised procedure which gives an idea of the bulk components that make up a fuel, which relate closely to its combustion behavior. Proximate analysis was done to determine the percentage volatile matter content, percentage ash content, moisture content and percentage content of fixed carbon of the briquettes.

Percentage volatile matter (PVM)

The PVM was determined by pulverising 2g of briquettes sample in a crucible and placing it in an oven until a constant weight (A) was obtained. The briquettes were then kept in a furnace at a temperature of 550 ^{o}C for 10 minutes and weighed after cooling in a dessicator to obtain (B). The PVM was then calculated using equation 1:

$$PVM = \frac{A-B}{A} \times 100 \qquad \text{(Eq. 1)}$$

Percentage Ash content (PAC)

The PAC was also determined by heating 2g of the briquette sample in the furnace at a temperature of 550 ^{o}C for 4hrs and weighed after cooling in a dessicator to obtain the weight of ash (C). The PAC was determined using equation 2:

$$PAC = \frac{C}{A} \times 100 \qquad \text{(Eq. 2)}$$

Percentage moisture content (PMC) on dry basis

The moisture content was found by weighing 2g of the briquette sample (E) and oven drying it at 105 ^{o}C until mass of the sample was constant. The change in weight (D) after 60 mins was then used to determine the sample's percentage moisture content using equation 3:

$$PMC_{(db)} = \frac{D}{E} \times 100 \qquad \text{(Eq. 3)}$$

Percentage fixed carbon (PFC)

The PFC was calculated by subtracting the sum of percentage volatile matter (PVM) and percentage ash content (PAC) and percentage moisture content from 100 as shown in equation 4:

$$\text{Fixed Carbon} = 100\% - (PAC + PMC + PVM) \quad \text{(Eq. 4)}$$

Estimation of important chemical elements that make up biomass, namely carbon, hydrogen, oxygen, nitrogen and sulphur were determined through 'ultimate' analysis.These properties were determined in accordance with ASTM analytical methods as prescribed by Jenkins *et al.* (1998). The calorific value of the samples was determined using a bomb calorimeter in accordance with ASTM E711 - 87 (2004). Density of the briquettes was calculated from the ratio of the mass to the volume of briquette in accordance with the method used by Rabier *et al.* (2006).

Of critical importance in the survey which the consumers responded to, include effect of the burning rate of the briquettes, heat output, ease of ignition of the briquettes, rate of devolatisation (how fast the briquettes burned), burning time or combustibility rating (how long the briquette burned before restocking when they are used in cooking and heating), sparking ability, smoke generation and any other effects regarding the burning of the briquettes.

Market survey

10kg of the sawdust charcoal briquettes was given to each of the 60 potential users sampled. The potential users sampled involved households and local hospitality industries operators (e.g. restaurants, hotels, wayside food vendors and bakeries). A survey was then conducted among the recipients of the briquette in order to establish their acceptability and willingness to use the briquettes. The survey was conducted through the administration of structured questionnaires a week after the distribution of the briquettes.

Results and Discussions

Physical characteristics of the briquettes

The quality of the sampled briquettes assessed on the basis of its physical condition was very good. The external surface was smooth and the structure of the cross-section was compact and homogenous. The density of the sawdust charcoal briquette was found to be 1100kg/m^3 which is reasonable and falls within the range recommended by Grover *et al*. (1994) for sawdust briquette produced by screw extrusion process. The hole in the center helps in combustion because of sufficient circulation of air. It also provides sufficient toughness to withstand exposure and shocks of transportation and storage.

Physico-chemical characteristics

The result of the physico-chemical characteristics of the sawdust charcoal briquette is presented in (Table 1).

Proximate analysis		Ultimate analysis		Heating value
Parameter	Value (%)	Parameter	Value (%)	
Volatile matter	71	Carbon	53.07	
Ash content	2.6	Hydrogen	4.1	4820 KCal/kg
Moisture content	5.7	Oxygen	39.6	
Fixed carbon	20.7	Sulphur	0.302	

Nitrogen	0.28

Table 1: Physico-chemical characteristics of sawdust charcoal briquette

Proximate analysis

The proximate analysis of the briquettes examined in this study were limited to percentage volatile matter, percentage ash, percentage fixed carbon and moisture content. The results presented in (Table 1) are discussed here after.

Moisture content

According to Yang *et al.* (2005), moisture content is a very important property which can greatly affect the burning characteristics of biomass. Aina *et al.* (2009) also reported that, moisture content is one of the main parameters determining briquette quality as lower moisture content of briquettes implies higher calorific value. Moisture content affects both the internal temperature history within the solid, due to endothermic evaporation, and the total energy that is needed to bring the solid up to the pyrolytic temperature (Zaror and Pyle, 1982). From Table 1, moisture content of the sawdust charcoal briquette was 5.7% db. This is within the limits of 15% recommended by Wilaipon (2008) and Grover and Mishra (1996), for briquetting of agro-residues. Most durable briquettes of sawdust are of the moisture content of 5% (Aina *et al.*, 2009). Wamukonya and Jenkins (1995), also recommended that, the range of values (7.7-15.1%) and (12-20%) for sawdust and wheat straw briquettes respectively are good for storability and combustibility of briquettes.

Volatile matter, ash content and fixed Carbon

Volatile matter represents the components of carbon, hydrogen and oxygen present in the biomass that when heated turn to vapour, usually a mixture of short and long chain hydrocarbons (Chaney, 2010). Volatile content has been shown to influence the thermal behaviour of solid fuels (Loo and Koppejan, 2008), but this is also influenced by the structure and bonding within the fuel. Chaney (2010) reported that, low-grade fuels, such as dung, tend to have a low volatile content resulting in smouldering combustion which De Souza and Sandberg (2004) described as a heterogeneous flameless combustion process which occurs on the surface or within the porous fuel. They further stated that, it results in incomplete combustion which leads to significant amount of smoke and toxic gases being released.

From the proximate analysis, the percentage content of volatile matter for the sawdust charcoal briquette was 71%. Ash which is the non-combustible component of biomass was determined to be 2.6%. According to Kim *et al.* (2001), ash has a significant influence on the heat transfer to the surface of the fuel, as well as the diffusion of oxygen to the fuel surface during char combustion. The values of volatile matter and ash content observed in this study are good and acceptable. Loo and Koppejan (2008), reported that, the higher the fuel's ash content, the lower its calorific value. *Ibid,* again reported that, biomass generally has a volatile content of around 70-86% of the weight of the dry biomass which makes biomass a more reactive fuel giving a much faster combustion rate during the devolatisation phase than other fuels such coal.

The fixed carbon of a fuel which is the percentage of carbon available for char combustion was determined to be 20.7%. This is not equal to the total amount of carbon in the fuel (the ultimate carbon) since a significant amount is released as hydrocarbons in the volatiles.

Ultimate analysis

From the result of ultimate analysis, the composition of the sawdust charcoal briquette, analysed on an "as received basis", showed 53.07% carbon, 4.1% hydrogen, 39.6% oxygen, 0.28% nitrogen, and 0.302% sulphur. The results agrees with the observations made by Chaney (2010) who reported, that, analysis of biomass using the gas-analysis procedures revealed the principal constituent as carbon, which comprises between 30 to 60% of the dry matter and typically 30 to 40% oxygen. Hydrogen being the third main constituent makes up between about 5-6% and nitrogen and sulphur (and chlorine) normally makes up less than 1% of dry biomass.

The amount of carbon and hydrogen content in the sample examined is very satisfactory as they contribute immensely to the combustibility of any substance in which they are found, (Musa, 2007). Jenkins *et al,* (1998) reported that, the resulting composition of biomass affects its combustion characteristics as the total overall mass decrease in the fuel during the volatile combustion phase of the combustion process as the hydrogen to carbon ratio of the fuel increases, and to a lesser extent, as the oxygen to carbon ratio increases. The low sulphur and nitrogen contents reported is a welcome development as there will be minimal release of sulphur and nitrogen oxides into the atmosphere which is an indication that the burning of the briquettes as fuel will not pollute the environment, (Enweremadu, *et al.*, 2004). Chaney (2010), also reports that, nitrogen, sulphur and chlorine are significant in the formation of harmful emissions and have an effect on reactions forming ash.

Calorific value

Heat value or calorific value determines the energy content of a fuel. It is the property of biomass fuel that depends on its chemical composition and moisture content. The most important fuel property is its calorific or heat value (Aina *et al.*, 2009). The calorific value calculated for sawdust charcoal briquette was 20,175.81kJ/kg (4820 Kcal/kg). This energy value is sufficient enough to produce heat required for household cooking and small scale industrial cottage applications. The results compares well with the results of heating value of sawdust briquette obtained by Chaiklangmuang *et al.* (2008) and most biomass energy for examples, almond shell briquette - 19,490KJ/kg (Jenkins *et al.*,1998), corncob briquette - 20,890 KJ/kg (Oladeji, 2010), cowpea- 14,372.93 kJ/kg, and soybeans-12,953 kJ/kg (Enweremadu, *et al*., 2004).

Respondents' perception on usage of the sawdust charcoal briquette

As shown in (Table 2), the following observations were made in response to the use of the briquettes by the potential users. With ease to ignite, 97% of the respondents indicated it was easy to ignite the briquette. 78% of the respondents also indicated that combustibility rating/burning time was quite long if they compare to the same amount of charcoal they use for their cooking and heating activities. 76% were of the perception that the heat output from the briquette was quite high compared to other fuels such as charcoal which they have been using. On the rate of devolatisation, 75% responded that, though the briquette has high heat output it burned slowly. The responds implies that the sawdust charcoal briquette used in this study ignites more easily and burn with high intensity for a long time.

More importantly, all the respondents indicated that, the briquettes burned without sparks and smoke. Low ash content was also observed. This shows that the sawdust charcoal briquette will be a better alternative to charcoal and firewood. This agrees Emerhi (2011), who reported that, briquettes improves health by providing a cleaner burning fuel and also provides a better alternative to firewood (40% more efficient, better and longer burning time) as well as helps to protect the environment by reducing the number of trees cut for firewood. Finally, 93% of the respondents indicated their willingness to use the briquettes if available and not very expensive.

Parameter		**Response (%)**	
Usage of product	Cooking	Grilling	Barbequing
	72	18	10
Ease of ignition	Easy	Difficult	
	97	3	
Convenience	Very good	Good	Poor
	27	68	5
Rate of devolatisation	Fast	Slow	Moderate
	6	85	9
Heat output intensity	High	Moderate	Low
	76	20	4
Combustibility rate /burning time	Long time	Short time	
	78	22	
Ash generated	Low	High	
	100	0	
Smoke/sparks	Yes	No	
	100	0	
Eagerness to use	Willing	Not sure	
	93	7	

Table 2: A matrix of user's perception on usage of sawdust charcoal briquette

Conclusion

The findings of this study have shown that, charcoal briquettes produced from sawdust would make good biomass fuel. The physico-chemical characteristics of the briquette assessed in this study showed that the briquettes manufactured from the sawdust has low moisture content, high calorific value and low ash content. There is also an indication that, the briquette is environmental friendly and will help reduce the health hazard associated with the use of fuel wood and reduce deforestation. The survey has revealed that sawdust usually generated in large quantities and usually burned to pollute the environment can be converted into good quality, highly storable and durable high-grade solid fuel briquettes that will be suitable for both domestic and industrial energy production for heat generation.

It can therefore be concluded that, indeed, there is future and market potential for biomass briquettes in the country since the survey revealed a positive attitude for the use of biomass briquettes by the respondents.

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