Effect of Starch and Gum Arabic Binders in the Combustion Characteristics of Briquette Prepared from Sawdust

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Effect of Starch and Gum Arabic Binders in the Combustion Characteristics of Briquette Prepared from Sawdust

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Abstract—The effect of starch and gum arabic as binders in the combustion characteristics of briquette prepared from sawdust of different ratios was investigated. Briquettes of sawdust were produced by mixing with different binders and agglomerate using starch paste and gum arabic. The mixture was compressed at 110kN using manually operated hydraulic briquette machine and sun dried. Water boiling test was employed to obtain percentage heat utilized, specific fuel consumption and time spent to boil 1kg water. The calorific value, the volatile matter and flame temperature were determined. Results showed that the briquette formed using starch as a binder performed better in all aspect than the gum arabic.

Keywords— Binders, Briquette, Sawdust, Starch, Gum Arabic.

1. Introduction

INDUSTRIALIZATION has made energy absolutely essential to manufacturing, commerce, transportation, comfort, agriculture, lighting and our daily activities. Importance of energy differs for different social-economic setting. For developed nations, energy abundance may mean difference between economic growth and a period of economic decline in a country and possibly, a shift in lifestyles from energy extravagance to moderation. High-energy consumption has been associated with higher quality of life, which in turn is related to Gross National Product (GNP). Economic development amongst nations has drawn interest to global energy resource inventories as well as regional or country wise energy source endowments. Source of energy can be grouped into renewable and non-renewable. Renewable energy is infinite energy source obtained from the continuing or repetitive current of energy occurring in natural environment [1]. These sources include biomass, solar energy and wind energy. While, non-renewable energy is one, which is finite, exhaustible and cannot be replaced. These are type of energy obtained from static stores of energy that remain bound unless released by human interventions. Non-renewable energies such as fossil fuel, petroleum, coal, natural gases and nuclear fuels are some of the several available to man [2].

Due to oil crises, progress has been made considerably towards finding new sources of fuel under secure Western control, increasing diversity of supply and widely spread reserves of natural gas, which rapidly displaced oil in much non-transport uses. Nearly all the western world's energy still comes from fossil fuel that will become increasingly hard to secure. Affordable oil and gas are unlikely to last more than another century. As supplies reduces, prices will rise and use will increasingly be restricted to premium applications like in transport and plastics manufacture shortage will create a renewed risk of instability in international markets. Nigeria as a member of OPEC, which she joined in 1971, has been firstly a beneficiary and secondly, a victim of the price increases [3].

Wood was the first the major source of energy and was readily available, because extensive forests grew in many parts of the world and the amount of wood needed for heating and cooking was relatively modest. However, the situation changed when wood began to be used during the middle ages to make charcoal. The climate in many developing nations like Nigeria favours renewable energy, if only there is commitment on the part of government and stakeholders in energy matters in Nigeria to indicate or initiate major policies that would be supported by a variety of other measure including targets, energy studies and strategies. One of such alternative source of energy is biomass energy, which is highly favoured because of its result in cleaning environment. Briquetting this biomass for energy source utilization could also be the solution to the ever increasing energy crises and shortage of energy in the country.

1.1 Sawdust Briquettes

Briquette is the physic-mechanical conversion with or without an additive of dry loose sawdust of fine particles size into solid state characterized by a regular shape and high density [4]. These processes could also be defined as process of converting loose wastes or sawdust into a dense, compact and consolidated unit through the application of high pressure. Apart from the problems of transportation, storage and handling, the direct burning of sawdust in conventional grates and stove are associated with very low thermal efficiencies and widespread of air pollution. In addition, a large percentage of un-burnt carbonaceous ash has to be disposed. Briquette of this waste could militate against these pollution problems while at the same time making use of this important industrial/domestic energy source. The briquettes produced are normally of two forms: carbonized and non-carbonized, carbonized briquettes are formed when biomass is subjected to a destructive distillation in a large closed reactor devoid of oxygen and quench after attaining a predetermined temperature. On the other side, non-carbonized briquettes are plain briquettes produced without undergoing carbonization process.

In Nigeria, a lot of research work had been done on the utilization of sawdust for domestic cooking using improved burning stone [5-9] while attempt had been made to densify the sawdust with appropriate equipment fabricated by the raw materials Research and Development Council in collaboration with Abubakar Tafawa Balewa University, Bauchi [10]. There has been various research works at the Federal University of Technologies, in both Minna and Akure on the suitability of utilizing briquettes fuel as high-grade solid fuel [11-15]. This involved the use of common sawdust with pat kernel shell adds line to improve calorific value. Water boiling test will be used to simply simulate the standard cooking procedures. Therefore, the current research is focused utilization of sawdust biomass for domestic supply of energy. It investigates the effect of starch and gum arabic binders in the combustion characteristics of briquette prepared from sawdust and properties such as calorific value (CV), volatile matter, flame temperature, percentage heat utilized (PHU), specific fuel consumption (SFC) and time spent in boiling were determined to evaluate its performance.

2. THEORETICAL BACKGROUND

2.1 The Calorific values of Samples

The calorific value of a fuel is the amount of energy liberated by burning a unit mass of the fuel. The calorific value of the biomass briquette is expressed as;

$$E_f = \frac{P_f \times t}{m_f} \qquad (1)$$

Where: E_f is calorific values of the fuel (KJ/Kg); m_f is mass of fuel burnt (kg); P_f is power output of the fuel (W); t is the time (s).

2.2 Percentage Heat Utilized

Percentage Heat Utilized (P.H.U) is the ratio of the net heat supplied to the water and the net heat liberated by the fuel. It is given as;

$$P.H.U = \frac{m_w\, C_p(T_b - T_i) + m_e L}{m_f \times E_f} \times 100 \qquad (2)$$

Where: m_w is mass of water in the pot (kg); m_e mass of water evaporated (kg); m_f is mass of fuel burnt (kg); T_i is Initial temperature of water (K); T_b is boiling temperature of water (K); c_p is Specific heat of water (KJ/KgK); L is Latent heat of temperature (KJ/Kg); E_f is calorific values of the fuel (KJ/Kg).

2.3 Specific Fuel Consumption (S.F.C)

The Specific Fuel Consumption (S.F.C) is the ratio of the mass biomass briquette burnt to the mass of water boiled. It is given as;

$$S.F.C = \frac{m_f}{m_w} \qquad (3)$$

Where: m_w is mass of water in the pot (kg); m_f is Mass of fuel burnt (kg).

2.4 Burning Rate

The burning rate is the rate at which a certain mass of fuel is combusted in air. It is given as:

$$B.R. = \frac{m_f}{t} \qquad (4)$$

Where: m is Mass of fuel burnt (kg) and t is the time (s).

3. MATERIALS AND METHODS

3.1 Materials and Sample Preparation

Sawdust sample used in this research was collected from timber market, Minna and divided into three different portions. The first sample contains raw sawdust without briquetting medium. The second sample is a measured quantity of sawdust briquetted using starch and the third sample is an equal quantity of sawdust with gum arabic as the briquetting medium. Prior to its separation into three parts, the sawdust (biomass) was screened of impurities like sand, metallic objects and chips of wood. It was sun dried to reduce moisture content and sieved using 2mm sieve to ensure uniform grain size and ease of compression. The ratio employed in this study was based on previous work of [12]. Other equipment used in this study include; starch paste, gum Arabic, water, weighing balance, briquette machine, briquette stove (Figure 1(a)), cooking pot, bomb calorimeter and crucible.

The starch paste and gum Arabic were made into non-viscous gel preparatory to briquette. The samples were mixed at different proportion. Starch and gum Arabic, which is a binder, was also added to enhance binding force. A manually operated hydraulic Briquette machine designed and fabricated in the Federal University of Technology, Minna was used for the compression of the samples into cylindrical shaped briquettes. The machine is equipped with pressure gauge, a hand lever, with a mould capable of producing 15 briquettes at the same time. Briquettes of the various mixtures were made under maximum pressure of 110kN/m^2 to enhance perfect compassion. The pressure was then released gradually to eject the compressed briquettes. After each successive operation whereby cylindrical briquettes were obtained, the products were sun dried in open space as shown in Figure 1(b) to remove the inherent moisture content to a tolerable level.

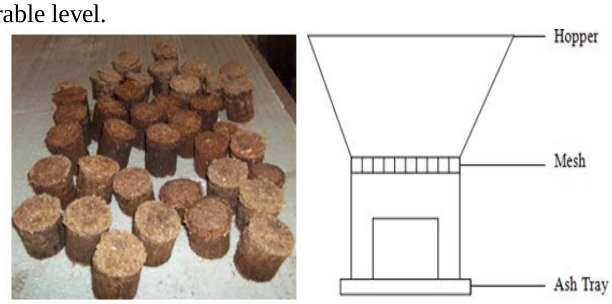

Figure 1: Materials; (a)-Cylindrical briquettes, (b)-Briquette stove

3.2 Experimental Procedure

Water boiling test (WBT) which has been used by other researchers [13] was used in this experiment. In conducting water-boiling test, the following procedures were taken. Dry weight of experiment materials like pot and stove were taken and recorded. The pot was filled with 1kg of water. The same mass (1kg of water), was maintained at each succession test and throughout the course of carrying out a water boiling test. The initial temperature of water was taken. The initial mass of briquettes fuel was taken before it was arranged in the briquette stove. A minimum of fifteen pieces of briquettes was used during each experiment. The fuel was then ignited by adding a little kerosene of (30g) to speed up the rate of initial combustion. It has been established [16] that 1g of kerosene is assumed to be about 2g of the briquettes and hence the kerosene used can be assumed to be part of briquette utilized. After the briquettes have been lit the pot containing 1kg of water was placed on the briquette stove and procedures continue. The temperature of the water was taken at 5 minutes interval until boiling took place. The time and the point of boiling was recorded and tagged "boiling phase". The mass of fuel remaining inside the stove at this point was also recorded on the analogue weighing balance. The pot of water was quickly transferred back to the stove and the process continued for the next 15 minutes after, which the above procedure was repeated, this point being tagged "high boiling phase". At the end of the low boiling phase, the mass of water and fuel remaining were recorded. The mass of charcoal and ash remaining were recorded.

To perform the flame temperature test, 5g of the samples was weighed into a silica crucible and transferred into muffle furnace, the temperature of the furnace was increased at a rate of 20^{o}C energy fine minute until active burning or flaming of the sample occurred. The temperature of ignition was then recorded. Performing the Volatile Matter, 2g of moisture free samples were weighed into tarred, covered with the lid, the crucible and its content placed in the muffle furnace. It was removed after exactly 15 minutes residence in the hot zone of the furnace just before attaining the ignition temperature and was then cooled in a desiccator. The crucible with its content was weighed and expressed as the weight loss % volatile matter. The values obtained were used for analysis. The whole process was repeated for all the samples of briquettes of different ratio of the biomass. From the data, the calorific values, Percentage Heat Utilized (PHU), Specific Fuel Consumption (SFC), flame temperature and time spent in boiling was calculated using equations (1) to (4).

4.0 RESULTS AND DISCUSSION

The results of various tests investigated in the current research for calorific values, Percentage Heat Utilized (PHU), Specific Fuel Consumption (SFC), flame temperature and time spent in boiling are presented in Figures 2 to 7.

4.1 Calorific values

The calorific values of raw sawdust, sawdust briquette starch and sawdust briquette with gum-arabic are shown Figure 2. The results show that the non-briquette sawdust has a calorific value of 17.1 MJ/kg and will serve as a base for the comparison of the calorific values of the binders used. Figure 2 shows that the sample using starch as binder has a calorific value of 16.50MJ/kg, while the briquette using gum-arabic as binder has a calorific value of 15.7MJ/kg. These values show that using starch as a binder for briquette fuel has better performance than gum Arabic.

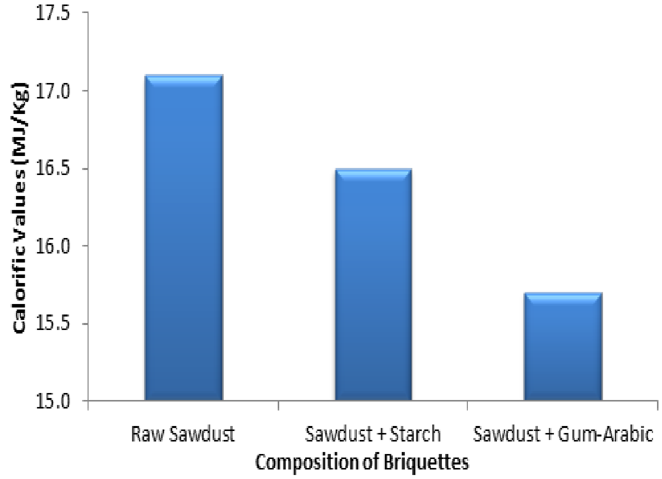

Figure 2: Calorific values of Briquettes

4.2 Flame temperature and Volatile matter

Figures 3 and 4 show that the non-briquette sawdust has a flame temperature and percentage volatile matter of 380^{o}C and 69% respectively. It was observed that the sample with higher calorific value has a higher flame temperature and vice versa. It was also noted that factors such as the plantation age and the moisture content of the residue could affect the calorific value and flame temperature of a particular biomass. This could be confirmed by the values of percentage volatile matter in each sample. The sample with the highest flame temperature of 380^{o}C has 69% of volatile matter. Figure 3 and 4 show that the sample using starch as binder has a flame temperature of 340^{o}C and a volatile matter of 62%, while the briquette using gum-arabic as binder has a flame temperature 290^{o}C and a volatile matter of 53%.

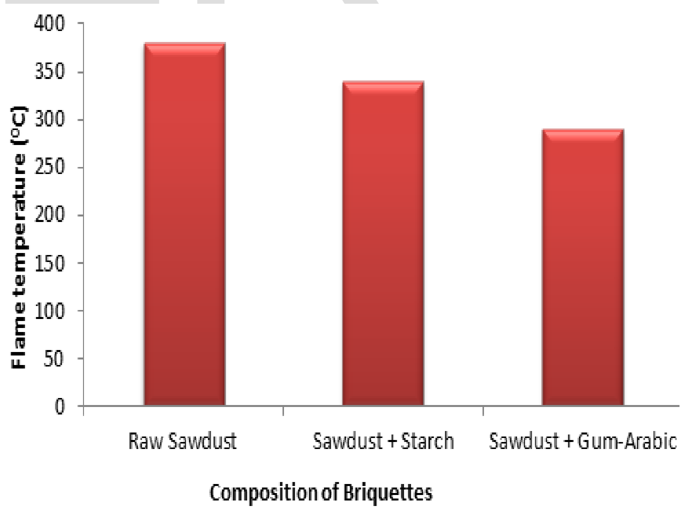

Figure 3: Flame temperature

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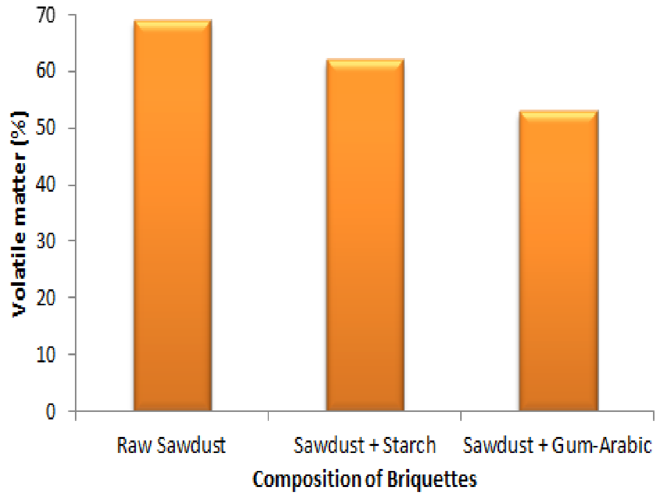

Figure 4: Percentage Volatile matter

4.3 Percentage heat utilized

The percentage heat utilized (PHU) during water test for raw sawdust, starch binder and gum-arabic binder are 39.7%, 33.06% and 28.23% respectively. Thus, the fuel with a higher PHU and high carbon content is a better fuel as shown in Figure 5.

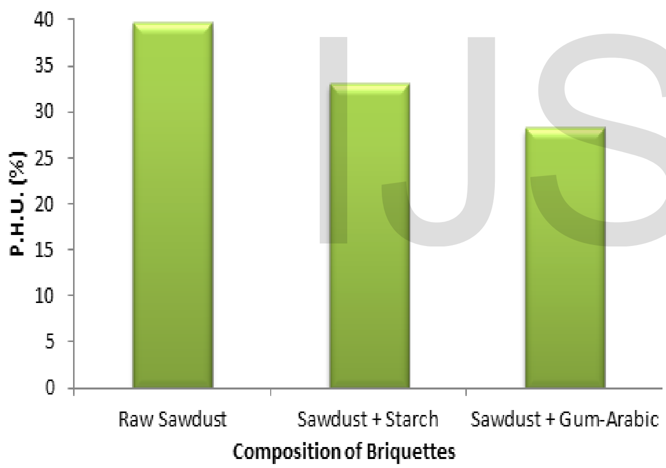

Figure 5: Percentage Heat Utilized

4.4 Specific fuel consumption

The specific fuel consumption (SFC) during water test for raw sawdust, starch binder briquette and gum-arabic binder briquette are 274.5KJ/kg, 227.3KJ/kg and 208.5KJ/kg respectively as shown in Figure 6. It implies that the raw sawdust could be used for rapid cooking while the others could be utilized for both low and high cooking particularly in bakery where there is need for heat retention in the oven.

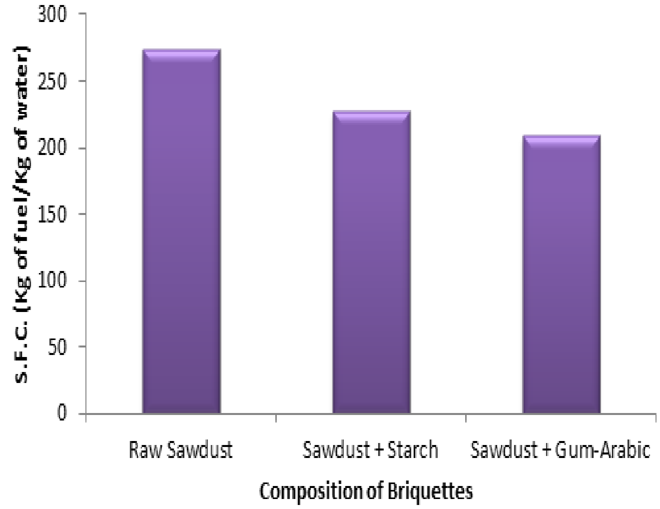

Figure 6: Specific Fuel Consumption

4.5 Time spent in boiling

The time spent in boiling (TSB) 1kg of water using raw sawdust, starch binder briquette and gum-arabic binder briquette are 23mins, 28mins and 35mins respectively as shown in Figure 7. The observed results may be due to a mixture of the biomass and the briquetting additives and also the presence of pores within the sawdust grains which might have been increased due to the addition of the briquette. The pores holding air or moisture have the effect of facilitating the escape of volatile gases and the breakdown of the structure as the briquette is burnt.

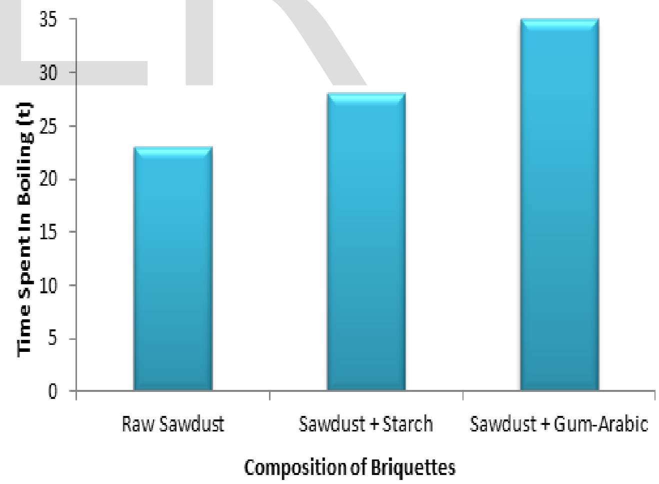

Figure 7: Time Spent In Boiling

5. CONCLUSIONS

The effects of binders on the combustion characteristics of sawdust (waste) have been investigated. Starch paste and gum Arabic was used to agglomerate the sawdust mixture together and utilized for high-grade solid fuel. The results obtained for calorific values, percentage volatile content, flame temperature, percentage heat utilized, specific fuel consumption and time taken in boiling showed that starch is has a better performance as a binder than gum arabic. Although, it was revealed that the calorific values of the briquettes of different hard wood species involved in this study did not vary greatly, marginal increment was observed ranging from 16.5–17.1 MJ/kg while the flame temperature varied greatly between 340°C and 380°C.Thus, it can be said that raw sawdust could be used for rapid cooking in households while others could be utilized for both low and high rapid cooking particularly in bakery where there is need for heat retention in the oven.

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