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USING PALM KERNEL SHELL BRIQUETTES IN FIRING CRUCIBLE FURNACE FOR LOW TEMPERATURE MELTING METALS

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Abstract: One of the uses of fossil fuels which are finite and non-renewable is for firing non-ferrous melting furnace in our metal industries. Early exhaustion coupled with their environmental pollution associated with their burning, necessitated the search for alternatives. So agricultural waste briquette such as palm kernel shell briquette was considered in this study. Lead, zinc, aluminum, brass and bronze were selected for melting. The briquettes were used to fire nonferrous melting furnace to melt lead, zinc, aluminum. Brass and bonze. Combustion, melting and flue gas temperatures were measured and their variations with time were shown. The results showed that, lead zinc and aluminum melted and reached their pouring temperatures of 425°C in 55 minutes, 526°C in 55 minutes and 736°C in 80 minutes respectively. Brass and bronze could only be heated to maximum temperatures of 883°C in 85 minutes and 826°C in 85 minutes respectively. It can be concluded that agricultural waste briquettes are good alternative renewable energy sources for firing crucible furnace for low temperature melting metals.
Keywords: Palm kernel shell briquettes, melting furnace, lead, zinc, aluminum, combustion, melting, temperature

1. INTRODUCTION

Based on the method of generating heat, furnaces are broadly classified into two types namely combustion type (using fuels) and electric type (Abed, 2013) stated by (Adeodu et al., 2017). The combustion type furnace can be broadly classified as oil fired, coal fired or gas fired (Adeodu et al., 2017). One of the obvious problems of developing countries is generation of insufficient energy to sustain enough economic activities that will catalyze industrial growth (Oriaku et al., 2017). In Nigeria, most especially in rural areas, electricity supply is epileptic besides the increase in tariff by Electricity Distribution Companies. Supply of oil and gas that is finite or not a renewable energy source dwindles with high cost and inherent environmental pollution, coal which is also a nonrenewable energy source, though sparsely available, but the technology of using it in order to improve on its slow response to temperature control and reduce its environmental pollution is limited. All these issues mitigate the use of electricity and fossil fuels (coal, oil and gas) in firing furnace. Hence there is so much pressure on the use of wood and its derivative charcoal for firing furnace besides its use for firing cookstove.

Fuel wood demand is 39 million tonnes per annum and it is about 37.4% of the total energy demand and the highest single share of all the energy forms (Energy National Commission of Nigeria, 2005; Sambo, 2009) and it is expected to rise to about 213.4x103 metric tonnes, while the supply would decrease to about 28.4x103 metric tonnes by the year 2030 (Adegbulugbe, 1994; Davies and Abolude, 2013). So the need to search for alternative fuels for firing non-ferrous melting furnace is not only because of the problems associated with the use of electricity and fossil fuels but also due to deforestation and probable little availability in the nearest future. Therefore, agricultural waste (biomass) energy has been attracting attention as an energy source since almost zero net carbon dioxide accumulation in the atmosphere from biomass production and utilization can be achieved.

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The carbon dioxide released during combustion process is compensated by the carbon dioxide consumption in photosynthesis (Han, 2004; Davies and Abolude, 2013)

In Nigeria, the oil palm tree generally grows in the rain forest region close to the coastal areas and adjacent to some inland waterways. Palm kernel shells are derived from the oil palm tree. According to Ndoke(2018), Nigerian Institute for Oil palm Research (NIFOR) stated that the two predominant varieties of palm fruits namely tenera and dura; produce about 1.5 million tonnes of palm kernel shells per annum in Nigeria. Some of these palm kernel shell are used in loose form to fire cookstove in rural areas and are also utilized by blacksmiths after they have been charred to burn off the remaining oils in them (Amoako et al., 2016). Moreso, they are used as solid fuels to fire boilers. However large quantities of the palm kernel shell are dumped indiscriminately without use thereby causing environmental hazard. Generally, using agricultural waste in loose form for firing cockstove, forge or oven or boiler results in widespread air pollution. So to mitigate this, briquetting these agricultural waste before use has been advocated for. Notably,the production, characterization and use of palm kernel shell briquettes have been carried out by Ugwu and Agbo, (2011); Adeniyi et al(2014); Chin and Shiraz, (2013); Muraina et al(2017); Kavalek, et al(2012); Akintude(2012); Alireza et al (2017); Mohammed and Olugbade(2015); Kurniawan et al (2017); Syamsuddin and Rizal(2013); Abdullahi et al(2017); Sing et al(2013); Olugbade and Mohammed(2015); Mahidin et al(2016). Little or no work is reported in literature where palm kernel shell briquette is used to fire non-ferrous melting furnace. So the aim of this research work is to experimentally investigate the feasibility of using palm kernel shell briquette for firing non-ferrous melting furnace for melting low temperature metals and alloys.

2. EXPERIMENTAL METHOD

12kg of lead sample was put in a crucible. The crucible with its lead content was put inside the non-ferrous melting furnace that is fired with agricultural waste briquettes that was developed by Musa and Akinbode (2012). The furnace was charged with 15.5Kg of palm kernel shell and lit with match sticks by adding dried waste papers to commence ignition. After that the blower was powered. The melting temperature of the lead was measured by a K- type thermocouple manufactured in China by Nigbo Taisuo Tech. ltd, inserted in the crucible. The combustion temperature of the palm kernel shell briquettes was measured by three K- type thermocouples with their probes situated in three equally spaced points in the circumference of the furnace combustion chamber. However, arithmetic mean of the measured temperature was taken as the combustion temperature of the palm kernel shell briquettes in line with the works of Grant (1997). Flue gas temperature was measured at the chimney by inserting the probe of a K-type thermocouple. All the measurements were carried out after every five minutes of firing the furnace.

After using lead for the experiment, 12kg each of zinc, aluminum brass and bronze were individually used in the same vein. 15.5Kg of palm kernel shell briquettes was initially used to charge the furnace for melting each of the selected samples. But when melting aluminum and it was further charged with 2.5Kg of the briquettes in an interval of 60minutes. In the turn of brass and bronze it was further charged with 2.5kg in three consecutive times in intervals of 40 minutes.

The initial weight of 15.5Kg of the briquettes used for charging the furnace was as result of the designed capacity of the furnace with a view to ensuring proper mix between the supplied air and the briquettes. The subsequent weights of the briquettes used for charging were to make up for the combusted briquettes in the furnace, whenever there are unanticipated drops in combustion temperature and melting temperature of the non-ferrous metals. The furnace being fired with palm kernel shell briquettes for melting one of the samples is shown in Figure 1.

Figure 1. The furnace being fired with palm kernel shell briquettes

After each operation, the furnace was evacuated and allowed to cool for 24 hours before the next operation. The ashes deposited were weighed and the partially burnt briquettes and char were also weighed. These were done in order to determine the palm kernel shell briquette (fuel) burn rates. So the fuel burn rate was evaluated using the relation stated as

$$\dot{M}_f = \frac{M_{ib} - M_{ob}}{T} \quad (1)$$

where
$\dot{M}_f$ is Fuel burn rate in Kg/s
M_{ib} is the initial weight of individual Briquettes in Kg
M_{ob} is the weight of partially burnt, unburnt briquettes, char and ash in Kg, and
T is the melting period in seconds.

From the time of firing the furnace to the time the measured melting temperature falls within the range of the pouring temperatures of individual non-ferrous metal (lead, zinc and aluminum) was the duration of each test. However for brass and bronze whose melting and pouring temperatures could not be attained, the tests were terminated after 150 minutes. Figures 2 shows the open furnace when aluminum metal melted and attained its pouring temperature and figure 3 shows the crucible containing the molten metal being removed from the furnace for pouring. The evacuation of the furnace of ash and unburnt briquettes is shown in figure 4.

Figure 2. An opened non-ferrous melting furnace fired with palm kernel shell briquette when aluminum attained its pouring temperature

Figure 3. The crucible containing molten aluminum at its pouring temperature

Figure 4. Evacuation of the furnace ash and unburnt briquettes

3. RESULTS AND DISCUSSION

The variation of combustion, lead melting and flue gas temperature with time using palm kernel shell briquettes is shown in Figure 5.

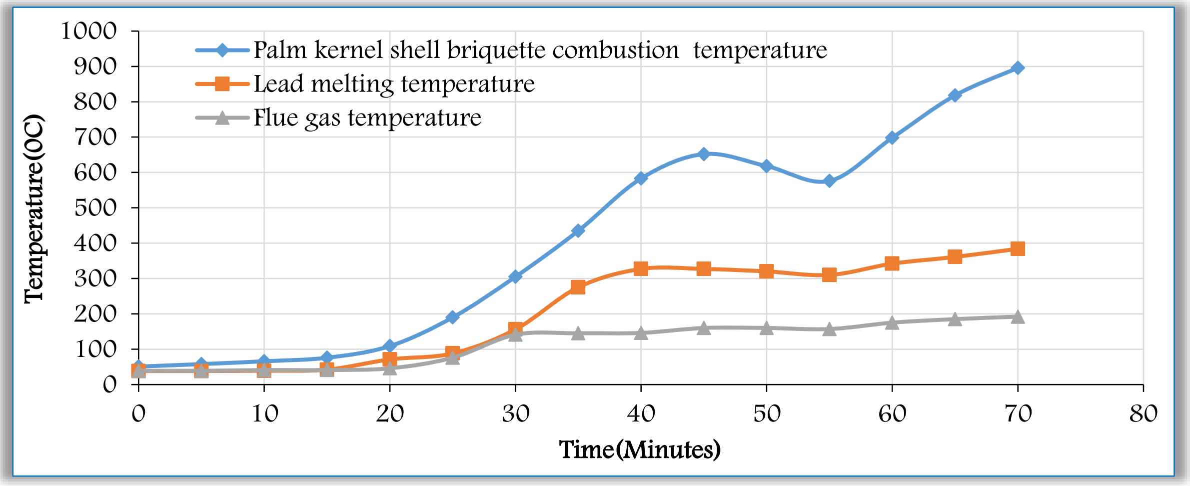

Figure 5. Variation of combustion, lead melting and flue gas temperature with time using palm kernel shell briquettes

It can be seen from figure 5 that as the combustion temperature increased steadily, the melting, and flue gas temperature also increased steadily when lead was melted. That is, between 0 and 55minutes. This may be attributed to single loading of the briquettes. Nevertheless, the palm kernel briquette fired furnaces was able to melt lead in 35 minutes and bring it to its pouring temperatures of 425^{0}C in 55 minutes. The variation of combustion, zinc melting and flue gas temperature with time using palm kernel shell briquette is shown in figure 6.

It can be seen from figure 6 that as the combustion temperature increased steadily, the melting, and flue gas temperature also increased steadily when zinc was melted. That is, between 0 and 55minutes for zinc. This may be attributed to single loading of the briquettes. Nevertheless, the palm kernel briquette fired furnaces was able to melt zinc in 45 minutes and bring it to a pouring temperature of, 526ºC in 55 minutes. The variation of combustion, aluminum melting and flue gas temperature with time using palm kernel shell briquettes is shown in Figure 7.

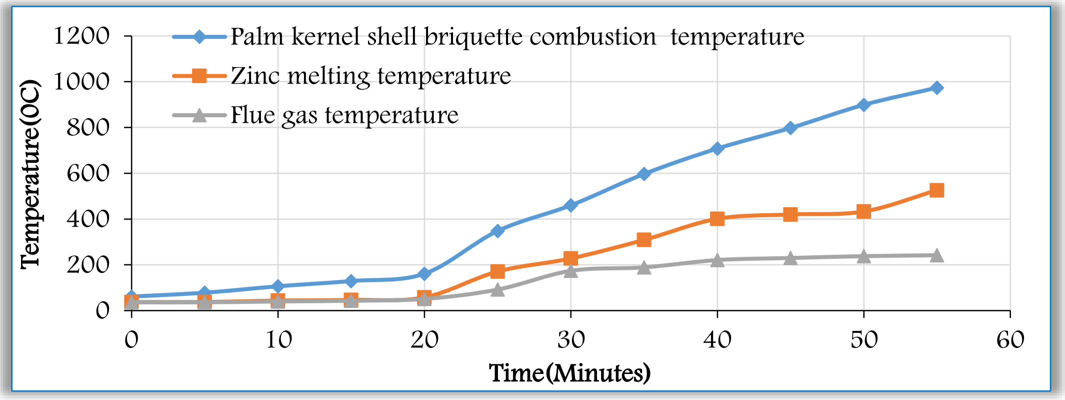

Figure 6. Variation of combustion, zinc melting and flue gas temperature with time using palm kernel shell briquettes

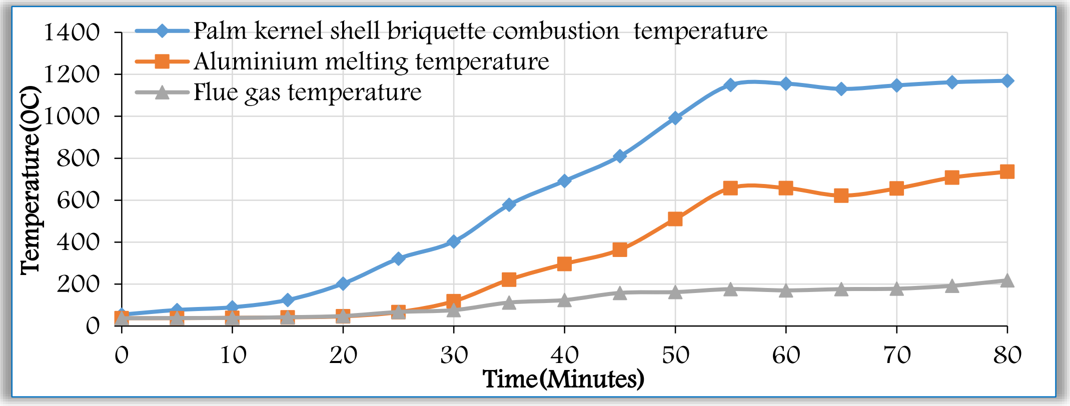

Figure 7. Variation of combustion, aluminum melting and flue gas temperature with time using palm kernel shell briquettes

In melting aluminum, drops in combustion temperature with corresponding drops in melting and flue gas temperature were experienced as evident in figure 7. That is, between 60 and 65minutes for aluminum. Nevertheless, the palm kernel briquette fired furnaces was able to melt lead, zinc and aluminum in 55 minutes and bring it to its pouring temperatures of 736ºC in 80 minutes. The variation of combustion, brass melting and flue gas temperature with time using palm kernel shell briquettes is shown in figure 8.

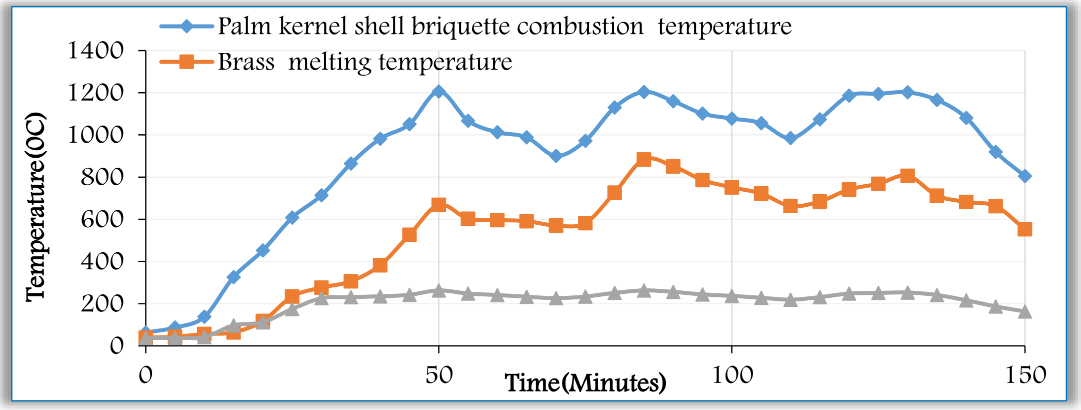

Figure 8. Variation of combustion, brass melting and flue gas temperature with time using palm kernel shell briquettes

In melting brass drops in combustion temperature with corresponding drops in melting and flue gas temperature were experienced. That is, between 50 and 70minutes, 90 and 110minutes, 135 and 150minutes for brass as seen in figures 8. Nevertheless, the palm kernel briquette fired furnace was able to raise the temperature of brass to maximum of 883ºC in 85 minutes and bronze to a maximum temperature of 826°C in 85minutes. The variation of combustion, bronze melting and flue gas temperature with time using palm kernel shell briquettes is shown in figure 9.

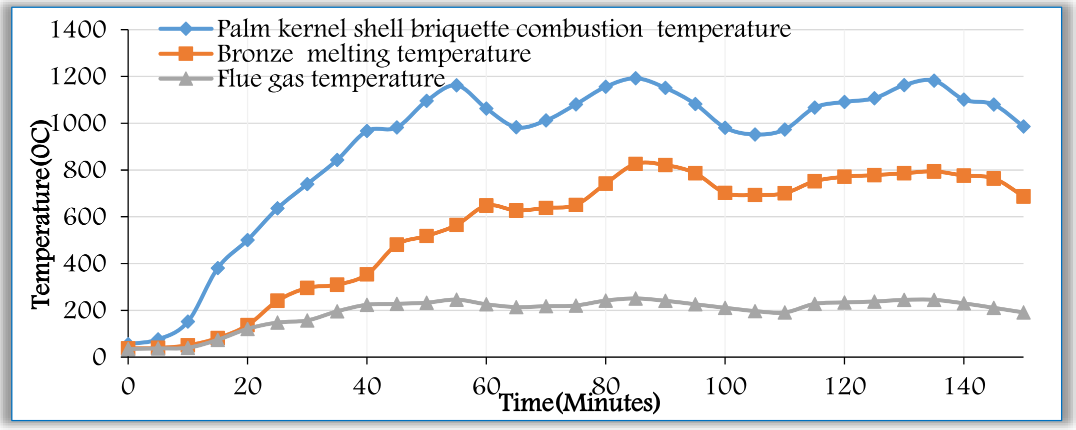

Figure 9. Variation of combustion, bronze melting and flue gas temperature with time using palm kernel shell briquettes

In melting bronze, drops in combustion temperature with corresponding drops in melting and flue gas temperature were experienced. That is, between 50 and 65 minutes, 85 and 105 minutes, 135 and 150 minutes for bronze, as seen in figure 9. Nevertheless, the palm kernel briquette fired furnaces was able to raise the temperature of bronze to maximum of 826°C in 85 minutes. The weights, calculated burn rates and ash deposits of palm kernel shell briquette for firing the melting furnace are shown in Table 1.

Table 1. Weights, Burn Rates and Ash Deposits of Palm Kernel Shell Briquette for Firing the Melting Furnace

Types of non-ferrous	Weight of briquettes fed(kg)	Weight of un-burnt briquettes(kg)	Weight of ash (kg)	Weight of briquettes used (kg)	Duration (mins)	Burn rates (kg/s)
Lead	15.5	6.58	0.71	8.21	55	0.0025
Zinc	15.5	3.62	0.80	11.08	55	0.0034
Aluminum	18	4.26	1.03	12.71	80	0.0026
Brass	23	6.6	1.2	15.2	150	0.0017
Bronze	23	7.10	1.43	14.47	150	0.0016

From the results shown in Table 1, highest burn rate of 0.0034kg/s was achieved when zinc was melted and the least of 0.0016 kg/s was attained when bronze was melted. According to Mohammed and Olugbade (2015), the changes in surface area of the palm kernel shell accounted for the variations in burning rate and energy released during combustion. The varied spaces between the briquettes in the combustion chamber of the furnace as a result of charging and the varied air-fuel ratio also led to the variation of burn rates of the briquettes.

4. CONCLUSION

Palm kernel shell were identified to be abundantly available, the non-ferrous melting furnace was fired with the individual briquettes to melt specific non-ferrous metals and their performances were evaluated, in terms of melting capabilities. The temperature of combustion, melting and flue gas were measured with thermocouples. The melting time and temperature were found to be dependent on the non-ferrous alloy being melted. The furnace fuelled with palm kernel shell briquettes was able to melt and bring lead, zinc and aluminum to their respective pouring temperatures. The result of this research has therefore revealed that palm kernel shell briquettes can be used as renewable energy source for melting lead, zinc aluminum and all other non-ferrous metals and alloy whose melting and pouring temperatures are lower than those of lead, zinc and aluminum. More so, it can be used to preheat brass and bronze in our metal industries.

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