International Journal of Modelling & Applied Science Research
Published by Cambridge Research and Publications

Vol. 25 No.9
September, 2022.

PHYSICAL AND COMBUSTION CHARACTERISTIC OF BRIQUETTES OF RAW AND CHAR DERIVED FROM PALM KERNEL SHELL AND COAL: A COMPARATIVE STUDY.

IBRAHIM A. INUWA; & SHITU MOHAMMED
School of Sciences Federal College of Education, Yola.

Abstract

Fuel physiognomies have been a vital energy source for heat and thermal conversion. In this study, palm kernel shell (PKS) raw and biochar briquettes, and coal are compared in order to obtain a suitable and efficient solid fuel as an alternative means for domestic and small scale industrial usage. The different properties of the samples were tested using proximate, ultimate and combustion analyses to estimate its potential and rightness as a fuel feedstock. Biochar were produced by pyrolysing the PKS raw sample at 400 °C under 30 °C / min heating rate, 2 mL flow rate and 2 hours retention time. The biochar briquette had calorific value of 29.83 MJ/kg, while coal and raw sample had 26.21 and 20.46 MJ/kg. Among the samples tested, biochar contained the lowest moisture 2.56 wt% and the highest elemental carbon 72.42 wt%. In water boiling test, burning rate, specific fuel consumption, percentage heat utilized or thermal efficiency, power output and ignition time were also determined. The results showed that biochar briquette has the highest thermal efficiency of 21.74% with power output of 77.03 kJ/min. Conclusively, this study found biochar-briquettes with a maximum advantage of efficiency as a potential to supplement energy supply in developing countries.

Keywords: *Coal, Biochar - Briquette, Combustion,*

Nomenclature

C_{pw} = Specific heat capacity of water (j/kgK)

M_f = mass of feedstock (g)

Mf = Moisture free

wt% = weight percentage

M_w = Mass of water in the pot (kg)

T_o = Initial Temperature of water (K)

T_b = Boiling Temperature of the water (K)

M_c = Mass of water evaporated (kg)

L_e = Latent heat of evaporation (kj/kg)

M_f = Mass of fuel burn (kg)

E_f = Calorific value of the fuel (MJ/kg)

t = Time taken to burn fuel (sec)

Introduction

Dumping large amount of agricultural residues in developing countries causes a detrimental effect to the environment. The over dependence on fossil fuel and the improper utilization of the wastes are consequences of environmental pollution [1]. Hence, the researches have now shifted towards harnessing the use of renewable energy sources which contributes to about 12% of today's world energy supply [2]. The proper utilization of wastes residues for renewable energy resource has the benefit of not only saving our planet from over-dependence on fossil fuel but also to transmute world economy to be competitive, technically feasible, environmentally admissible and easily available [3]. Improper utilization and the use of fossil fuel causes a lot of environmental problems and remained responsible for enhancement of greenhouse gas (GHG), emissions of pollutants, genesis of climate change and imbalance between energy demand and supply that eventually leads to global warming (GW) [4].

Briquetting is the way of transforming agricultural residues into a more convenient size by densification. This increases the homogeneity and controlled the combustion performance fuel. Additionally it helps greatly in the storage and serves as transportation fuel. Briquettes can be fabricated with or without the aid of external binders [5]. The common forms of briquettes are the bio - briquettes and coal - briquettes . Biomass briquettes are obtained from ordinary agricultural residues which includes the charcoal briquettes by compaction of agricultural residues to briquettes, for the purpose of thermal application [6]. It is also a process of compaction of residues into a product of higher density than it original material [7]. Briquettes have efficiency over raw agricultural residues and biochar fuel in terms of better heat intensity, transportation and storage [8]. Therefore, the aim of this work is to compare the physical and combustion characteristic of briquettes of raw and biochar derived from palm kernel shell and coal.

Feedstock Preparation and method

Palm kernel shell (PKS), oil palm waste were collected from United Oil Palm Industry in the northern region of peninsular Malaysia, Bituminous coal from Global Mineral Kuching, Sarawak and Starch was processed from cassava obtained from Pulau Pinang Malaysia.

The palm kernel shell sample was received in wet condition and dried in the conventional oven for 24 hrs at 105 ^{o}C to removed or reduced moisture content to ≤10% in order to avoid the growth of orange fungus and grey mould.

The bituminous coal sample was air dried for 7 days to reduce the moisture content. It was then grounded into a smaller particles size for proximate, ultimate and calorific value analyses.

Cassava tubers collected were washed, peeled, ground and pressed to extract the liquid content. The liquid was filtered and the filtrate was allowed to stay for one day so that the starch would separate from the water. After that the upper liquid layer was carefully decanted. The starch was sun dried for three days to reduce the, moisture content.

The biochar product was produced by pyrolysing PKS raw sample using a lab-scale pyrolysis system. In the experiment conducted, 250g of PKS raw samples were fed into the stainless steel Pyrolyzer at 400 ^{o}C pyrolysis temperature, 30 °C /min heating rate, 2 hours retention and 2 mL /min nitrogen flow rate. Both high quality and moderately high quality biochar can be produced at around 400 ^{o}C, since at this temperature; moisture, cellulose and hemicellulose were almost being eliminated, leaving behind mostly carbon and lignin [9].

Proximate, ultimate and HHV Analyses of the Materials

PKS raw, biochar and coal samples were grounded in preparation for the proximate ultimate and high calorific value (HHV) analysis in line with the ASTM standard. The moisture content, volatile matter and ash content of all the three samples were determined by ASTM E871-82, ASTM E872-82 and ASTM E1755-01 respectively. The fixed carbon was computated by subtracting from the difference. The calorific value (HHV) of the sample was analyzed using Oxygen Bomb Calorimeter of model –IKA C200. The total carbon hydrogen, nitrogen and sulphur content were analyzed using a Perkin Elmer 2400 analyzer.

Briquette Samples production.

The briquette of PKS raw and biochar samples were produced by grinding them into power form. A 2.5 % cassava starch each of the total mass of the sample was used as the binder. The briquettes were formed by compression the pulp in the mould with a simple prototype briquette machine. The machine worked on hydraulic ram principle. The blend char concentration was filled into the mould and compressed by a 2-tonne hydraulic jack at a pressure of 100 kg/cm^2, dwell time of 2 min was observed, and briquettes were ejected immediately after the dwell time. The briquettes sample was air dried at an ambient temperature and relative humidity of 30 - 34 ^oC for five days and 60 - 70 %, respectively.

Combustion Experiment

In this study, the performance of PKS raw, biochar briquette fuel and coal combustion were carried out using outdoor wood fuel stoves. The water boiling test was implemented to determine the fuel burning characteristics based on the following approached of some authors:

Percentage Heat Utilized (P.H.U) or Thermal Efficiency

The thermal efficiency measures how the heat generated by the fuel is utilized in boiling the water

$$P.H.U = \frac{M_w C_{pw}(T_b - T_o) + M_c L_e}{m_f E_f} \times 100\% \qquad (1)$$

Power Output

This determines the available amount of energy released from the fuel in a given time.

$$P = \frac{M_f \times E_f}{t} \tag{2}$$

Specific Fuel Consumption (SFC)

The amount of solid fuel required to boiling a given quantity of water, divided by the total weight of boiling water

$$S.F.C = \frac{M_f}{M_w} \tag{3}$$

Burning Rate

The burning rate (g/min) which measures how economically the fuel is consumed and is determined using the

$$Burning\ rate = \frac{mass\ of\ fuel\ consumed\ (g)}{Total\ time\ taken\ (\text{min})} \tag{4}$$

Results and Discussion

The results obtained from the study are presented in Table 1 and Figures 1 and 2. The figures include the results of temperature profile and combustion characteristics for all the three samples.

Table 1: Proximate, ultimate and HHV results for PKS raw, biochar and coal.

Samples	*Proximate analysis (Mf wt %)*				*Ultimate analysis (Mf wt %)*				*HHV*
	Moisture	Volatile	Ash	Fixed carbon	C	H	N	S	*MJ/kg*
PKS Raw	5.30	71.50	7.11	16.09	53.70	3.40	0.47	0.20	20.46
PKS Char	2.56	37.59		54.49	72.42	3.97	0.38	0.10	29.83
Coal	9.87	36.08		47.51	64.66	7.91	1.16	0.80	26.21

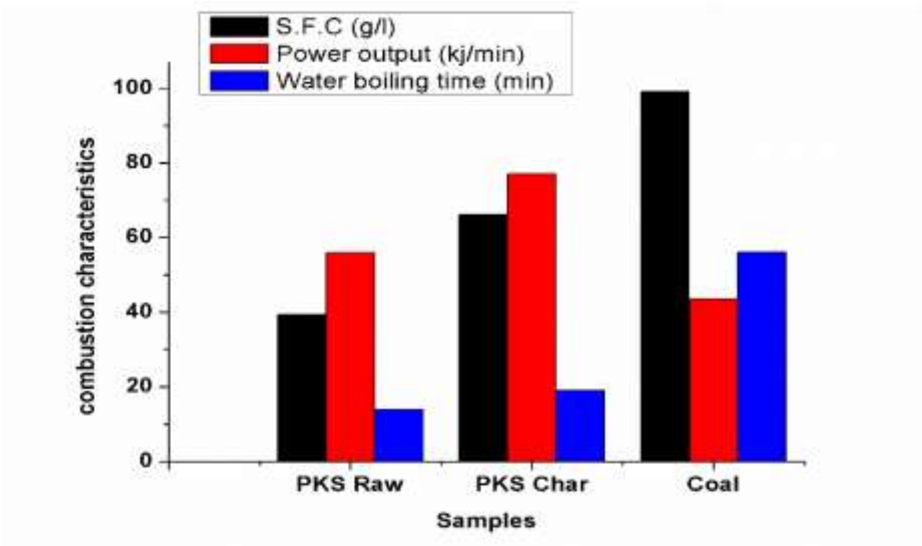

Fig. 1: Combustion characteristic of PKS raw, biochar Briquettes and Pure Coal.

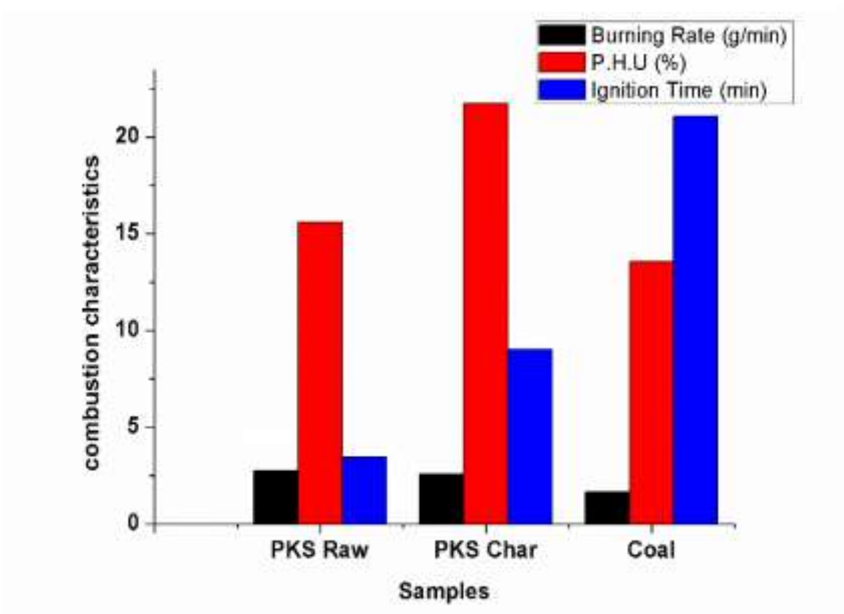

Fig. 2: Combustion characteristic of PKS raw, biochar Briquettes and Pure Coal.

The proximate, ultimate and calorific values results of PKS raw, biochar and coal are presented in Table 1. The calorific values of biochar product were relatively higher than the respective values of its raw sample and coal. This was caused due to the high moisture and lower carbon of 5.30 %, 53.70 % in raw sample and 9.87 %, 64.66% coal sample respectively. The higher calorific value found in PKS biochar gives it better combustion properties as a compered with its raw material and coal for sustainable solid fuel [10]. However, the high volatility in PKS raw sample resolved to ignite easily and burn faster than biochar and coal sample.

Figure 1 shows that PKS raw briquette has the lowest fuel consumption of 39.35 g/L compered to biochar briquette and coal of 66.00 g/L and 99.09 g/L respectively. This indicates that more fuel would be reqiured in boiling the same quatity of water with coal samples. The same figure also indicates that the highest power output of 77.03 kJ/min was founded in biochar briquette compered to PKS raw briquitte and coal sample of 55.91 and 43.57 kJ/min.

Figure 2 indicates that the burning rate of briquette produced from PKS raw and biochar 2.73 g/min and 2.58 g/min is higher than coal sample of 1.65 g/min. This shows that PKS raw briquette and biochar briquettes burn more effectively than coal sample [11]. The same figure also indicates that, the biochar briquette shows the highest fuel efficiency of 21.74 % compered to PKS raw briqutte and coal sample of 15.60 % and 13.54 % respectively. The highest fuel efficiency in biochar briquette qualified the quality of a good solid fuel.

It can be seen that PKS raw briquette and biochar briquettes have the shorter ignition time of 3.45 and 9.00 min compered to coal sample with the longest of 21.05 min (Figure 2). Inginating higher rank coal is relatively more tougher and perhaps needed greater energy chemicals igniters (1000 or 2500 J) [12].

CONCLUSION

In this research work, study of physical and combustion characteristics of briquette of raw and biochar derived from palm kernel shell and bituminous coal sample were carried out. The results indicate that the biochar briquette had the highest calorific value of 29.83 MJ/kg, while coal sample and PKS raw briquette had 26.21 and 20.46 MJ/kg. In water boiling test (WBT), results showed that biochar briquette also has the highest thermal efficiency of 21.74 % with power output of 77.03 kJ/min. The biochar briquette had the maximum advantage of efficiency as a potential to supplement energy supply in developing countries.

Reference

CHAPTER 1 1. P. Grover and S. Mishra, “ Biomass briquetting”, in technology and practices, Food and Agriculture Organization of the United Nations, 1996, CHAPTER 2 2. A. Demirbas and G. Arin, "An overview of biomass pyrolysis", Energy sources, 2002, 24(5): p. 471-482.

CHAPTER 3 3. M. A. A. Mohammed, A. Salmiaton, W. W. Azlina, M. M. Amran, A. Fakhru'l-Razi, and Y. H. Taufiq-Yap, "Hydrogen rich gas from oil palm biomass as a potential source of renewable energy in Malaysia", Renewable and Sustainable Energy Reviews, (2011), 15(2), 1258-1270.

CHAPTER 4 4. S. E. Hosseini, M .A. Wahid, and A. Ganjehkaviri, "An overview of renewable hydrogen production from thermochemical process of oil palm solid waste in Malaysia", Energy Conversion and Management, 2015, 94: p. 415-429.

CHAPTER 5 5. E. Mihajlović, D. Mitić, and M. Stojiljković, "Development and designing of machines and technologies for briquette and pellet manufacturing by dry and wet process", Thermal Science, 2006, 10(4): p. 131-141.

CHAPTER 6 6. J. F. Martin, R. M. A. Pineda, J.A. Manaay, S. R. A. Handa, and A. B. Ocreto, "Design and development of charcoal briquetting machine", USM R&D Journal, (2008), 16(2), 85-90.7. J.

CHAPTER 7 7. Oladeji, and O. Oyetunji, "Investigations into physical and fuel characteristics of briquettes produced from cassava and yam peels", J. Eng. Technol. Policy, 2013, 3(7): p. 40-46.

CHAPTER 8 8. E. Emerhi, "Physical and combustion properties of briquettes produced from sawdust of three hardwood species and different organic binders", Advances in Applied Science Research, 2011, 2(6): p. 236-246.

CHAPTER 9 9. W. H. Chen, and P. C. Kuo "Astudy on torrefaction of various biomass materials and its impact on lignocellulosic structure simulated by a thermogravimetry" Energy,2010,35(6): p2580-86

CHAPTER 10 10. A. A. Rahman, F. Sulaiman, and N. Abdullah, " The physical, chemical and combustion characteristics of EFB fuel briquettes", In AIP Conference Proceedings, (2015, April), (Vol. 1657, p. 040010).

CHAPTER 11 11. P. Wilaipon, "Density equation of cassava-stalk briquettes under moderate die-pressure", American Journal of Applied Sciences, 2010, 7(5): p. 698-701.

CHAPTER 12 12. C. Man, and J. Gibbins, "Factors affecting coal particle ignition under oxyfuel combustion atmospheres", Fuel, 2011, 90(1): p. 294-304.