Global Scientific JOURNALS

GSJ: Volume 14, Issue 3, March 2026, Online: ISSN 2320-9186

www.globalscientificjournal.com

DETERMINATION OF PHYSICAL AND COMBUSTION PROPERTIES OF BLENDED BRIQUETTES OF CARBONIZED SAWDUST AND BANANA LEAVES AND PSEUDO STEM WASTE

BY:

OGADIS JEPKEMEI

ABSTRACT

Currently in Kenya, biomass such as sawdust from sawmill industries and agro wastes, like banana leaves and pseudo stem, are potential sources of renewable energy. However, in most cases biomass is normally discarded in the fields with no value addition and also little information exists on their use as fuel in blended briquettes. Consequently, this study investigated the use of carbonized sawdust and banana waste as raw materials for briquettes production as an alternative energy source. Specifically, the study aimed at characterizing physical properties of the raw materials, fabricating blended briquettes at varying mix ratios/particle sizes and characterizing physical and combustion properties of the blended briquettes. In the study, pseudo stem and banana leaves from *Musa acuminata AAA* species and sawdust from *Eucalyptus tree* species were collected, dried to 8 % moisture content, hammer milled, sieved and carbonized in muffle furnace at 400 °C for 5 minutes. The briquettes were then characterized in terms of mass density, durability index, ash content, moisture content, volatile matter and calorific value. Raw materials: sawdust, banana waste and molasses had moisture contents of 12.52 %, 14.63 % and 22.23 %; volatile matter of 25.32 %, 31.45 % and 43.25 %; calorific value of 15.92 MJ/kg, 12.35 MJ/kg and 11.24 MJ/kg; ash content of 5.79 %, 6.89 % and 8.00 %, respectively. The density ranged from 392.54 kg/m^3 to 681.21 kg/m^3. In conclusion, sawdust had better calorific value, lower ash and moisture contents, lower volatile matter and higher mass density than banana waste. From the study, it is recommended that briquettes with high and fine sawdust content (50% above) should be used owing to their good durability, low moisture content, low CO emission and higher calorific value. Future studies should determine effects of interaction between variables such as compaction pressure, blend ratio and particle sizes on combustion properties.

Key words : Calorific value, combustion characteristics and Physical characteristics

INTRODUCTION

Biomass is being highly promoted as an alternative energy resource for the fossil fuel, especially during the past three decades, the effect of escalating prices is attributed to factors such as world economic growth, declining value of the dollar and unrest in Middle East coupled with declining domestic oil supply (Banpast*et al*., 1997). A study by Kituyi *et al*. (2001) showed that about 15.4 million tons of fuel wood was consumed in 1997 and this was supplied by farm land trees, indigenous forests, woodlands and timber off-cuts from plants. Fuel wood supply has been declining in rural Africa (Jami*e al*., 2008). Various researchers have reported this shortage in Kenya (Marfa, Huber, *et al*., 2001; Maher, 2003; Ngetich*et al*., 2009). As a result, there is an increase in the utilization of crop residues by farmers to fulfill their energy requirements. Replacing traditional forms of biomass energy use with modern ones is expected to have a number of benefits such as a decrease in the emission of greenhouse gases and forest destruction; reduced health hazards; and an increase in energy availability (Janssen &Rutz, 2012).

The uncertainty of prices and supply of crude oil has prompted the search for alternative sources of energy to meet the evergrowing energy demand. By compacting these biomass, high density and energy concentrated solid material called briquettes are produced which can supplement existing energy sources. Biomass from forestry has been the main source of fuel wood in Kenya.. Furthermore, this study revealed very minimal utilization of crop residues as domestic fuel (about 1.4 million tons). However, fuel wood supply has been declining in rural Africa (Jama*et al*., 2008). For example, Mugo (1999) reported that a shortage of fuel wood supplies resulted in approximately, 40% of the farmers in western Kenya utilizing crop residues and cow dung as domestic energy sources. In other parts of western Kenya, rural households have resorted to buying crop residues in order to cater for their fuel needs (Maher, 2003).

Close to 70 % electricity supply in Kenya is hydro based. By December, 2012 approximately 1.8 million customers had been connected to electricity supply (Stima News, Jan., 2012) benefiting about 20 % of 38.6 million Kenyan (KNBS, 2009), leaving the rest of the population to seek alternative sources of energy. Similarly, wood accounts to about 70 % of total energy consumption in Kenya, benefitting 80 % of Kenyan population. It serves 90 % of rural households and 85 % of urban households (Mugo and Kituyi, 2002). About 47 % of Kenyan households use charcoal of which 82% and 34 % are urban households and rural households respectively (UNEP, 2006). The total annual charcoal production is 2.4 million tons, produced from the forests, but with the current forest cover of 1.7 % which is below the target of 10 %, there is need to search for sustainable energy sources.

Replacing traditional forms of biomass energy use with modern ones would have a number of benefits such as a decrease in the emission of greenhouse gases and forest destruction; reduced health hazards; and an increase in available energy (Janssen &Rutz, 2012). In addition, the utilization of biomass for energy production can contribute considerably to job creation, hence improving the rural economies and reducing rural urban migration (Openshaw, 2010; Thornley*et al.*, 2008). Elsewhere in the USA, America and Duncan (2001) study reported that over 66,000 rural jobs have also been created in biomass power generation and an additional 40,000 in biofuels.

This study aimed at producing blended briquettes at varying mixture ratios of sawdust and banana waste and determined their physical and combustion properties. It was anticipated that produced briquettes would supplement traditional fuels and save environmental degradation both by deforestation and pollutants emission from combusting fossil fuels.

EXPERIMENTAL METHODS

3.1 MATERIAL

The material used in this study consisted of sun-dried sawdust and banana waste which were ground, sieved, carbonized and compacted to produce briquettes. Materials were carbonized to increase the carbon content hence the heating value.Table 3.1 show sample preparation

Table 3.1 sample preparation

Sample No.	Weight of components (gm)			Weight of briquettes (gm)
	Saw dust	Banana waste	molasses	
1	50	0	20	50
2	40	10	20	50
3	30	20	20	50
4	25	25	20	50
5	20	30	20	50
6	10	40	20	50
7	0	50	20	50

3.1.1 Sawdust

Sawdust collected had a moisture content of about 28 %. It was sun dried to approximately 5 % moisture content and hammer milled before carbonizing at 400ºC for 5 minutes in the muffle furnace according to Gimba and Turoti (2008). The carbonized sawdust was then cooled to room temperature in the desiccator. After cooling, the materials were sieved to different particle sizes of 2.5 mm, 5 mm, 7 mm 9 mm and 11 mm following Zhang*et al.* (2012)(see Appendix EFig.E1 for sieves used in the study). The sieved materials were packed and sealed in separate labeled plastic bags to avoid absorption of moisture from the atmosphere.

3.1.2 Banana waste

Samples of dried banana leaves were obtained directly from harvested banana trees and only the leaves that were already dry were collected. The pseudo stem was obtained from harvested banana plants. By having high humidity, pseudo stem was pressed in a hydraulic press to remove the largest liquid fraction, and after that process, it was dried in a forced ventilation muffle at 60 ºC to a moisture content of 8%. The dried pseudo stem and banana leaves were hammer milled and sieved using a 2.5 mm sieve, to obtain fines with an average particle size of 2.5 mm. The milled pseudo stem and leaves were blended at the same ratios before mixing with carbonized sawdust as indicated in section 3.3.2.

3.1.3 Molasses

A commercial molasses was used in this study. 10 litres were bought from a hardware supplier and stored in a cold and dry place in the work shop. It was black in colour with a viscosity of 0.076 poise. In the current study, it was used as a binder during briquette manufacturing and its proportion was maintained at 20 % by mass in all briquettes made.

3.2 DETERMINATION OF PHYSICAL AND COMBUSTION PROPERTIES OF SAWDUST AND BANANA WASTE

3.2.1 Density

Density of sawdust and banana waste was determined according to ASAE S269.4 standards. Since density is property of mass against volume, the process of determining density was accomplished

$$\rho = \frac{m}{v} \qquad \text{Equation 3.1}$$

as follows. Both the mass and volume were measured and the measurements were computed and treated as the mass (m) and volume (v) in each case. Mass was measured using electronic balance and volume was determined after 5 MPa compaction in a mould measuring 50mm and 100 mm. The density was determined using the Equation 3.1:

Where ρ is density (g/cm^3)

m - is the mass (g)

v - is the volume of the briquette (cm^3)

3.2.2. Calorific value

Calorific (heating) value of biomass is indicative of the energy content of the fuel. A Parr 6200 oxygen bomb calorimeter (Parr Instrument Company, Moline, IL) was used to determine the calorific value of sawdust (see Appendix D Fig. D.9). One gram was placed in a stainless steel crucible, and the material in the vessel (bomb) ignited by a 2223 cotton fuse. The vessel was filled with oxygen and surrounded by a water jacket. Upon ignition, the released heat was transferred to the water jacket. The temperature rise in the water jacket was used by the calorimeter to calculate the heating value of the sample.

3.2.3 Ash content

The amount of ash-forming material present in fuel is an indication of suitability of sawdust as fuel. ASTM 03174-97 (39) was used as by Nopporn (2013). In this case an empty crucible was heated to a temperature 500^{o}C for 30 minutes in muffle furnace before the cover was placed over it and cooled over desiccant for one hour. Thereafter, one gram of the sample was put on the weighed crucible, covered and heated gradually to temperature of 725^{o}C within 2 hours. The crucible was then cooled in desiccators before weighing. Difference in mass gives the ash content.

3.2.4 Volatile matter

Volatile matter was determined using the standard method, ASTM E872-82 (2006) as used by Sotanndee*et al*., (2010). This process was carried out by heating empty crucible to temperature of 500^{o}C for 30 minutes in muffle furnace. The cover was then placed and cooled in desiccators for one hour. Thereafter, one gram of the sample was put in the weighed crucible and closed with tightly fitting cover so that carbon deposit did not burn away. The sample was then transferred into the muffle furnace, ignited and temperature allowed to rise to 950^{o}C and was maintained for 7 minutes. The crucible was then removed from the furnace, cooled in desiccators, weighed and difference in mass was volatile matter.

3.2.5 Moisture content

Moisture content was determined as per ASTM E1871-82 (2006) standard. Empty crucibles were heated to 105°C for duration of 1 hr. They were then removed from the oven, covered and cooled immediately in a desiccant for 30 minutes. One gram of each of the samples was then weighed, put in the crucibles then dried in an oven at 105°C for 24 hrs. The crucibles were cooled in desiccators to room temperature then weighed again. Difference in mass is the moisture content.

RESULTS AND DISCUSSION

4.1. PHYSICAL AND COMBUSTION PROPERTIES OF SAWDUST AND BANANA WASTE

Table 4.1 gives the physical (density) and combustion (calorific value, moisture content, ash content and volatile matter) properties of sawdust and banana waste determined from this study. Molasses had the highest density, ash content, moisture content and volatile matter. Comparing banana waste and sawdust, the former had higher ash content, moisture content and volatile matter while the latter had higher density and calorific value.

Table 4.1: Physical and Combustion Properties of Sawdust, Banana waste and Molasses.

Materials	**Density (Kg/m^3)**	**Calorific Value (MJ/kg)**	**Ash content (%)**	**Volatile Matter (%)**	**Moisture Content (%)**
Sawdust	681.21	15.92	5.79	25.32%	12.51
Banana waste	392.54	12.35	6.89	31.45%	14.63
Molasses	1330	11.24	8.00	43.25%	22.23

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

In the current study, blended briquettes produced from carbonized sawdust and banana waste were fabricated and characterized.

Sawdust has better calorific value (15.92 MJ/kg), lower ash content (5.79 %) and higher density (681.21 Kg/m^3) compared to 12.35 MJ/kg, 6.89 % and 392.54 Kg/m^3, respectively from banana waste under similar condition of measurements. On the other hand, banana waste has higher moisture content (14.63 %) and volatile matter (31.45 %) compared 12.51 % and 25.32 %, respectively from sawdust.

Moisture content of blended briquettes decreases with the increase in the sawdust content. However, there is no gain in moisture content reduction by increasing sawdust content in the blended briquette above 50%.

REFERENCES

Adapa, P. (2009, 10;06 10;22). Compaction Characteristics of Barley,Canola,Oat and Wheat Straw. *Biosystems engineering;Biosystems*.

Adegbulugbe, A. (1994). Energy-Environment. *Global Energy Issues*, 7-18.

Aina O, M., & K, S. (2009). Heat Energy from Value Added Sawdust Briquettes. *Environmental Management*, 21-35.

Abakr, Y. and Abasaeed, E. (2006). Experimental Evaluation of a Conical- Screw Briquetting

Machines for the Briquetting of Carbonized Cotton Stalks in Sudan. *Journal of Engineering Science and Technology,* 1:212-230

Aga, S. (2000). A Study of Densification of Pre-heated Sawdust, Msc. Thesis No. ET-90-4, Asian Institute of Technology, Thailand

Akinbami, J. (2001). Renewable Energy Resources and Technologies in Nigeria; Present Situation, Future Prospects and Policy Framework Mitigation and Adaptation Strategies for Global Change

Altun, E. Hicyianaz, K. and Bagci, S. (2004). Influence of Coal Briquettes Size on the Combustion Kinetics. *Fuel Processing Technology Journal*, 88:1345-1357

Ardayfio, D. (2006). The Fuel/ Energy Crisis in Sub Sahara Africa. Sustaining the Future, Economic, Social and Environmental Change in Sub-Sahara Africa. The United Nations University

ASTM (American Society for Testing and Materials), (2004a). Annual Books of ASTM Standards Parts Gaseous Fuel; Coal and Coke, Atmospheric Analysis, Easton Maryland, USA

ASTM (American Society for Testing and Materials), (2004b). Standard Test Methods for Gross Calorific Value of Refuse- Derived Fuel by Bomb Calorimeter Annual Books of ASTM Standards

Announssany, M. Richard, G. Recous, S. and Guerif, J. (2000). Change in Mechanical Properties of Wheat Straw due to Decomposition and Moisture. *Journal onApplied Engineering in Agriculture*, 16: 657-664

Banzaert, A. (2013). *PhD Thesis, Massachusettes*. USA: Institute of Technology,Cambridge.

Belen B. Bisare, N. B. (2010). Utilization of Cashew Nut Shell Residue for Charcoal Briquettes and activated carbon. *production journal of Wood Science*, 44,56-61.

Bhada, G. (2007). *Feasibility Analysis of Waste to Energy as a Key Component of Integrated Waste Management in Mumbai*,. India.

Bjorheden, R. (2006). Drivers behind the Development of Forest Energy in Sweden. *Biomass and Bioenergy 30(4):289-295.*

Bolufwi S. and Bamgboye A., (2008). . (n.d.). Physical Characteristics of Briguettes from Guinea Corn (Sorghum bi-colour) Redidue. *Agricultural Engineering International.The CIGR Ejournal. Manuscript 1364.*

Bamgboyo, I. and Bolufawi, S. (2010). Physical Characteristics of Briquettes from Guinea Corn(Sorghum Bi- color) Residues. *Agricultural Engineering Journal,* 1:1-10

Boyles, T. (2004). Combustion Properties of Biomass. *Journal on Fuel Processing Technology*. 54:17-26

Chaney, J. Clifford, M. and Wilson, R. (2009). An Experimental Study of the CombustionCharacteristics of Low Density Biomass Briquettes. *Biomass and Bio energy Journal*, 12: 505-509

Chin, O. and Siddiqui, K. (2000). Characteristics of Some Biomass Briquettes Prepared under Modest Die Pressures. *Journal on Biomass and Bio Energy,*18: 223-238

Chirchir,D.,Nyaanga,D., and Kitheko, J.,. (2013). Effects of Binders types and amount on physical and Combustion Characteristics of Biomass Composite Briquettes. . *International Journal of Engineering Research ,Science and Technology,2013/2(1)*.

Dam, V. Jeg, D. and Keijsers, E. (2004). Process for Production of High Density Performance Binderless from Coconut Husk Part 1: Lignin as Intrinsic Binder Resin. *Journals on Binder Resin,* 19:207–216

Demirbas, A. and Sahin, A. (2001). Evaluation of Biomass Residue; Briquetting Waste Papers and Wheat Straw Mixtures. *Journal on Fuel Processing Technology,*55: 175-183

Demirbas,A. (2007). Biomass Resource Facilities and Biomass Conversion Processing for Fuels and Chemicals. *Journal on Energy Conversion and Management*, 42: 57–78

Dermibas, A. (2004). Physical Properties of Briquettes from Waste Paper and Wheat Straw Mixtures. *Journal on Energy Conversion and Management*, 40:437-445

DOE (Department of Energy), (2009). Official Energy Statistics for USA Government. World Nominal Oil Prices Chronology, USA

DOE (Department of Energy), (2008). USA Energy Information on Annual Coal Report, USA

Eriksson S. and Prior M.,. (1990). *The Briquetting of Agriculture of Agricultural wastes For Fuel.* Food and Agricultural Organization Publication .

Etienne, P. (2007). Development of Energy Production System to Briquette Papyrus through Partial Pyrolytic Conversion, Biomass Energy Services and Technology

Enweremadu, C. Ojediran, J. Oladegi, J. and Afolabi, K. (2004). Evaluation of Energy Potential of Husks from Soyabeans and Cowpeas. *Journal on Sciences Focus,* 8:18-23

FAO. (1987). *Agriculture Production Yearbook.* Rome: Food and Agriculture Organization.

Faizal, H. Latiff, A. Mazlan, A. and Darus H. (2010). Physical and Combustion Characteristics of Biomass Residues from Palm oil Mills. *Journal on New Aspects of Fluid Mechanics and Environment,* 8:34-38

FAO (Food and Agriculture Organization), (2005). Industrial Charcoal Making. Food and Agricultural Organization of the United Nations

Geoffrey B. and Lars A. . (1985). *Agricultural Residues as a source of Fuel in Developing Countries.* London: IIED.

Girald, P. Fallot, A. and Dauriac, F. (2005). Technology State of Art Review of Existing and Emerging Technologies for the Large Scale Production of Bio fuel

GOK (Government of Kenya), (2007). Kenya Vision 2030. Government of Kenya, Nairobi
Greenberg, A. Mehling, A. Lee, M. and Bock, J. (2005). Tensile Behaviour of Biomass. *Journal of Materials Science*, 24: 49-54

Halyk, R. and Hurlbut, J. (2005). Tensile and Shear Strength Characteristics of Biomass. *Journal on Mechanical Properties of Biomass*, 11:56-57

Hayashi, H. and Nakashima, S. (2002). Synthesis of Trioctahedral Smectite from Rice Husk Ash as Agro-waste

Heinz, K. Siemers, W. and Stuven, U. (2003). Technical and Economic Assessment of Charcoal and Densified Fuel from Water Hyacinths and Cotton Stalks. *Journal on Fuel Processing Technology*,7: 23-42

Himraj, D. (2003). Fuel Substitution in Sub Sahara Africa. *Journal on Environmental Management*, 17:283-288