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Effect of Density on the Some Thermal Characteristics of Briquettes at Different Levels of Binder, Pressure and Particle Sizes

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ABSTRACT

The study evaluated the combustion properties of briquettes made from sawdust of different binder ratios of phytoplankton scum as binder at different compression pressure and particle sizes. The saw dust samples were collected, cleaned, sun-dried, milled and sieved into three particle sizes 0.5 mm (D1), 1.0 mm (D2) and 2.0 mm (D3). Phytoplankton scum was collected from stagnant fish ponds using scoop net. Water was drained out prior drying using oven until the weight was constant. It was ground to fine particle size using plate mill and later sieved to particle size 0.075 mm with Tyler sieve. The briquettes were produced at 3 particle sizes of 0.5 mm (S1), 1.0 mm (S2) and 2.0 mm (S3), four pressure levels of 2 MPa (P1), 4 MPa (P2), 6 MPa (P3) and 8 MPa (P4) and using 10, 20, 30, 40, and 50% phytoplankton scum by weight of each feedstock. Die dimension was 14.3 mm height and 4.7 mm diameter and compression was conducted by hydraulic press to form fuel briquettes with dwell time of 60 seconds. The obtained data was statistically analysed using Pearson Correlation Coefficient. There was significant negative relationship between relaxed density, specific fuel consumption and burning rate of the briquettes at different levels of compaction pressure and particle sizes. There was positive correlation between thermal fuel efficiency, ignition time, calorific values, water boiling time and relaxed density at the different binder ratio, compaction pressure and particle sizes (P<0.001).

Keywords: *Densification, particle size distribution, combustion, durability index, mechanical handling*

INTRODUCTION

The densification of biological material enhanced the density of briquettes. This is imperative because is one of the major determinants in both the saving in transportation and handling cost and also better the thermal characteristics of the original material. The physical and chemical properties of the original materials, the equipment used and its operating conditions are major factors that determined the density of briquettes [1]. Briquette and pellet densities of biomass for high pressure process ranged from 1,200 to 1400 kg/m^3 and 1,450 – 1500 kg/m^{3}was reported by Kaliyan and Morey [2]. Packing density of briquettes is lesser than the density of briquettes itself due to the fact that briquettes cannot be packed perfectly. Many scientists have conducted work on densification of biomass. According to Kaliyan and Morey [2] reported the gains in bulk densities in the range of 10-20 times from densification process. Particle sizes of biomass play a significant role in determining the durability, moisture content and density of any briquette [3]. It was reported that biomass of fine particles generally accepts more moisture than large particles. According to Olorunnisola [4] briquettes manufactured from larger particle size experienced more fissure points which leads to cracks and fracture in briquettes. The particles size ranged between 0.6 and 0.8 when used to produce briquettes will produced fuel briquettes of better good mechanical handling characteristics [2]. Biomass of fine particles will produce more durable and stable briquettes. Despite better briquettes is manufacture from fine particle sizes but the cost of production is quite enormous and expensive. Thus, mixture of various particle sizes of biomass to produce briquette with optimum quality is recommended [5]).

Fuel briquettes of higher density and strength are recommended. Briquettes density should be less than1.91 kg/m^2 [6]. Density is an important parameter for storage and transportation purposes. Briquettes with higher density are preferred as fuel because of their high calorific values and good combustion characteristics [7, 8]. Huge volume of agricultural and industrial waste that initial constitute nuisance are now turned into useful purposes such as fuel briquettes. Combustion characteristics of fuel briquettes depends on pre-treatment processes and material conditions such as temperature, particle size, binder types and compaction pressure [9, 10]. Some Scientists have worked on different range of compaction pressure (3-15MPa) and falls within the range of manually produced briquettes using hand press for the production briquettes [4, 5, 11]. Particle size varied between 0.6 and 4.7 mm were recommended for the production of briquettes [5, 12].

The production of briquette is described as an advanced fuel due to its clean burning nature and it can be preserved for long periods of time without deterioration and degradation. Micro enterprise can be established for the production of fuel briquettes from industrial and agricultural wastes to generate income. Utilization of sawdust and other agricultural waste can be viewed as important way of managing the wastes problem and contributing to environmental management as well as creating employment and generating income for those who are worst affected by it [13, 14, 15, 16, 17]. The upsurge in the demand for wood fuel consumption is considered as a major contributing factor to the fuel wood, global warming and deforestation crisis in Nigeria. Transition to a sustainable energy system is imperative to avert its current shortfall in the developing countries such as Nigeria [12].

MATERIALS AND METHODS

Experimental Procedure

Sawdust of white afara softwood (Terminalia superba) was collected from a sawmill industry. A total of 300 kg of white afara softwood collected from saw mill and packed in bags on 15th of June, 2015. Phytoplankton scum an aquatic plant was used as binder. Preliminary studies were conducted prior this main experimental work in order to investigate the possibility of using white afara sawdust and phytoplankton scum as binders for production of briquettes at different binder ratio (10, 20, 30, 40 and 50% by residue weight), particle sizes of 0.5 mm, 1.0 mm and 2.0 mm and compaction pressure, 2, 4,6 and 8 MPa.

Sawdust was cleaned and later pre-treated with hot water of temperature not less than 80oC to remove extraneous matters. Filtrate was removed and later rinse well with warm water prior drying using oven until the weight was constant. Phytoplankton scum was collected from stagnant fish ponds using scoop net. Water was drained out prior drying using oven until the weight was constant. It was ground to fine particle size using plate mill and later sieved to particle size 0.075 mm with Tyler sieve. Sawdust was ground to particle size distribution 0.50 – 3.0 mm, achieved by using Particle Size Analysis Equipment consisting of sieve shaker and Tyler sieves of various diameter or particles size openings. Tyler sieve was further used to obtain three particle sizes namely 0.5 mm, 1.0 mm 2.0 mm.

The ratio of sawdust to phytoplankton scum content in the mixture were 90:10, 80:20, 70:30, 60:40 and 50:50. The agitating process was carried out using mechanical mixer to enhance proper blending and homogenous mixture prior compaction. A steel cylindrical die of dimension 14.3 cm height and 4.7 cm in diameter was used for the purpose of this study. A known charge of sample was freely filled into the die. and placed under the hydraulic press machine for compaction into briquette. A known pressure was applied at a time to the charge material in the die and dwell period of 60 seconds before released using stop watch. Briquette formed was extruded and labelled for identification. Extruded briquettes were further dried in the over at 60oC for 24 hours. Dried briquettes were later packed inside high density cellophane bag for one week before the experiment. The combustion properties of briquettes which included the density, calorific values, specific fuel consumption, ignition time, burning rate, water boiling time and thermal fuel efficiency

Determination of relaxed density of briquette

The relaxed density of briquettes was determined after sun-dried for 14 days according to Olorunnisola [4].

Combustion characteristics of the briquettes

The calorific value of the sample was determined using Bomb Calorimeter according to (ASTM. E711-87) [18].

Water boiling time

Water boiling test was conducted according to Onuegbu et al.[19].

Burning rate

This determines the rate at which a certain mass of fuel is combusted in air. Fuel burning rate was determined according to Ndirika [20].

Ignition time

The ignition time was determined according to Davies and Abolude [1]

Evaluation of thermal fuel efficiency of briquettes sample

The thermal fuel efficiency of the briquette was calculated from equation [21].

Statistical analyses of data

The obtained data was statistically analysed using Statistical Analysis System (SAS) (2007) and Pearson Correlation coefficient.

Results And Discussion

Positive correlation was observed between thermal fuel efficiency and relaxed density at the four binder levels (Table 1). The minimum and maximum values were 0.55 and 0.83 ($P<0.001$). The result revealed that density of briquettes had a significant influenced on the thermal fuel efficiency of the briquettes. The correlation between ignition time and density exhibited positive, strong and significant ($P<0.001$). The lowest values of r was (0.75) B1 and highest value (0.89) B4. It was observed that at a higher level of binder the relationship between density and ignition time became significant. This showed that briquettes of higher density might observed delayed ignition time [1]. The correlation between calorific value and density of briquettes revealed significant positive interaction ($P<0.001$). The r values ranged between 0.71 (B1) and 0.84 (B4).

The relationship between density and specific fuel consumption indicated negative and significant ($P<0.001$). The values ranged from -0.63 (B2) to -0.87 (B3). The optimum binder corresponded to B3. It was observed that the higher the density, the lower the specific fuel consumption of briquettes. The relationship established between burning rate and density of the briquettes strong, negative and significant interaction ($P<0.001$). The values varied between -0.80 (B1) and -0.91 (B4). That is the higher the density, the lower the burning rate of briquettes. It was reported that the higher the density the lower the burning rate of the briquettes [11]. One of the major factors used to determine the quality of fuel briquettes is density and burning rate. The relationship between density and water boiling time showed strong, positive and significant relationship ($P<0.01$). The r- ranged from 0.68 (B1) to 0.93 (B4). The density of fuel briquettes has significant effect on water boiling time.

The observed relationship between fuel efficiency and relaxed density was positive and significant for all the pressure levels ($P<0.001$). The values varied from 0.81 (P1) to 0.84 (P2 and P4). This showed that relaxed density had strong influence on the thermal fuel efficiency of the briquettes. The relationship between ignition time and relaxed density was positive and significant ($P<0.001$). The lowest and the highest correlation coefficient corresponded to 0.69 for P3 and 0.86 for P2 respectively. The higher the relaxed density of the briquette, the longer is the ignition time. This is a positive development in densification process. Since heat energy is released gradually and steadily than low density briquette that burns easily. The present observation agrees with the findings of Demirbas and Sahin [22] and Davies and Davies [23] that as densities of the briquettes increased their ignitabilities decreased.

The calorific value and relaxed density of briquettes demonstrated positive and significant correlation at all compaction pressure levels ($P<0.001$). The variation ranged from 0.66 for P3 to 0.77 for P2. The relaxed density exhibited negative and significant correlation with specific fuel consumption ($P<0.001$). The values ranged between 0.75 (P3) and 0.89 (P4). The two parameters were negatively correlated and it was significant at $P<0.001$. The values varied from -0.81 (P3) to 0.91 (P4). It could be inferred that high density briquettes might have low burning rate. The burning rate of any fuel is a major factor that determined the quality of fuel either for domestic or commercial use. Therefore, lower density briquettes have a faster normalised burning rate compared to higher density briquettes. In this vein, the density of the fuel is increased, handling characteristics are improved, transportation cheaper and burning rate can be easily controlled [11]. Relaxed density correlated positively and significantly with the observed water boiling time for all the pressure levels (P<0.001). The mean correlation coefficient varied from 0.61 (P2) to 0.85 (P1).

A positive and significant relationship existed between thermal fuel efficiency and relaxed density (P<0.001). The r values ranged between 0.57 (D3) and 0.79 (D2). This indicated that the higher the relaxed density of any briquette, the higher is its fuel efficiency. The heat content of briquette of particle size 0.5mm might be released gradually than that of 4mm particle size. The interaction between the two parameters was positive and significant (P<0.001). The r values varied from 0.69 (D2 and D3) to 0.75 (D1). These values depicted a strong relationship. The highly density briquettes could take a longer time for it to burn and thereafter, the heat content is released gradually. The investigations revealed that particle sizes determine briquette porosities. The smaller the particle size, the higher will be the density, and on the contrary, the longer will be the ignition time [6]. The calorific value and relaxed density of briquettes demonstrated positive and significant correlation (P<0.005). The r values ranged between 0.56 for particle size 4mm and 0.91 for size 0.5mm.

The specific fuel consumption had negative and significant correlation with relaxed density. The r values varied from -0.58 for particle size 4mm to -0.87 for size 0.5mm. The two parameters were negatively and significantly correlated at P<0.001. The r values ranged between -0.65 (D2) and -0.88 (D1). It could be inferred that the higher the relaxed density of briquettes the lower the burning rate. The burning rate of any fuel is a major factor that determined the quality of fuel either for domestic or commercial use. Relaxed density demonstrated positive and significant correlation with the observed water boiling time (P<0.001). The r values varied from 0.49 (D3) to 0.80 (D1 and D2). It implied that briquettes of higher relaxed density might have higher water boiling time.

Table1. *Relationships among combustion characteristics of water hyacinth briquettes at different binder level*

Binder level	Combustion characteristics							
		RD	TFE	IT	CV	SFC	BR	WBT
B_1	RD	1.00						
	TFE	0.83**	1.00					
	IT	0.80***	0.75***	1.00				
	CV	0.76***	0.69***	0.69***	1.00			
	SFC	-0.67***	-0.85***	-0.70***	-0.59***	1.00		
	BR	-0.83***	-0.69***	-0.58***	-0.86***	0.72***	1.00	
	WBT	0.68***	0.63***	0.85***	0.61***	-0.97***	-0.78***	1.00
B_2	D	1.00						
	TFE	0.68***	1.00					
	IT	0.64***	0.86***	1.00				
	CV	0.71***	0.59***	0.82***	1.00			
	SFC	-0.63***	-0.66***	-0.78***	-0.63***	1.00		
	BR	-0.80***	-0.79***	-0.90***	-0.93***	0.94***	1.00	
	WBT	0.59***	0.62***	0.78***	0.81***	-0.65***	-0.49***	1.00
B_3	D	1.00						
	TFE	0.74***	1.00					
	IT	0.80***	0.78***	1.00				
	CV	0.63***	0.58***	0.78***	1.00			
	SFC	-0.87***	-0.70***	-0.80***	-0.62***	1.00		
	BR	-0.91***	-0.72***	-0.79***	-0.59***	0.92***	1.00	
	WBT	0.76**	0.39*	0.32 ns	0.20ns	-0.71***	-0.45**	1.00
B_4	D	1.00						
	TFE	0.55***	1.00					
	IT	0.67***	0.85**	1.00				
	CV	0.74**	0.21ns	0.09***	1.00			
	SFC	-0.79***	-0.76***	-0.86***	-0.19ns	1.00		
	BR	-0.89***	-0.70***	-0.64***	-0.47**	0.89**	1.00	
	WBT	0.93**	0.67***	0.87***	0.76*	-0.76***	-0.78***	1.00

*ns=not significant, *=significant at P<0.05, **=significant at P<0.01, ***=significant at P<0.001. D- density; TFE-thermal fuel efficiency; IT-ignition time; CV-calorific value; SFC-specific fuel consumption; BR-burning rate; WBR-water boiling time*

Table2. *Relationship among variables at different pressure*

Pressure	Combustion Characteristic							
		RD	FE	IT	CV	SFC	BR	BT
2 MPa	RD	1.00						
	FE	0.81***	1.00					
	IT	0.85***	0.93***	1.00				
	CV	0.74***	0.78***	0.81***	1.00			
	SFC	-0.79***	-.86***	-.88***	-0.68***	1.00		
	BR	-.83***	-.82***	-.87***	-0.69***	0.91***	1.00	
	BT	0.85***	0.88***	0.90***	0.74ns	-.86***	.90***	1.00
4 MPa	RD	1.00						
	FE	0.84***	1.00					
	IT	0.86***	0.83***	1.00				
	CV	0.77***	0.78***	0.80***	1.00			
	SFC	-0.84***	-.72***	-.86***	-0.57***	1.00		
	BR	-0.87***	-.71***	-.83***	-0.67***	0.90***	1.00	
	BT	0.61***	0.53***	0.67***	0.56***	-.74***	-57***	1.00
6 MPa	RD	1.00						
	FE	0.83***	1.00					
	IT	0.69***	0.87***	1.00				
	CV	0.66***	0.77***	0.79***	1.00			
	SFC	-0.75***	-.81***	-.86***	-0.56***	1.00		
	BR	-0.81***	-.79***	-.81***	-0.63***	0.90***	1.00	
	BT	0.71***	0.75***	0.90***	0.76***	-.84***	-.81***	1.00
8 MPa	RD	1.00						
	FE	0.75***	1.00					
	IT	0.79***	0.89	1.00				
	CV	0.43**	0.21ns	0.09***	1.00			
	SFC	-0.88***	-.76***	-.81***	-0.19ns	1.00		
	BR	-0.96***	-.70***	-.73***	-.47**	0.87***	1.00	
	BT	0.90***	0.67***	0.69***	0.40*	-.82***	.92***	1.00

*ns=not significant, *=significant at P<0.05, **=significant at P<0.01, ***=significant at P<0.001. D- density; TFE-thermal fuel efficiency; IT-ignition time; CV-calorific value; SFC-specific fuel consumption; BR-burning rate; BR-water boiling time*

Table3. *Correlation matrix of variables at different particle sizes*

Particle size		Combustion characteristic						
		RD	FE	IT	CV	SFC	BR	BT
0.5 mm	RD	1.00						
	FE	0.73***	1.00					
	IT	0.80***	0.77***	1.00				
	CV	0.91***	0.72***	0.90***	1.00			
	SFC	-0.87***	-.83***	-0.90***	-0.89***	1.00		
	BR	-0.88***	-0.86***	-0.87***	-0.88***	0.96***	1.00	
	BT	0.80***	0.66***	0.88***	0.89***	-0.83***	-0.83***	1.00
1.0 mm	RD	1.00						
	FE	0.70***	1.00					
	IT	0.69***	0.83***	1.00				
	CV	0.65***	0.68***	0.74***	1.00			
	SFC	-0.61***	-0.70***	-0.85***	-0.42***	1.00		
	BR	-0.65***	-0.70***	-0.92***	-0.69***	0.79***	1.00	
	BT	0.80***	0.66***	0.88***	0.89***	-0.83***	-0.83***	1.00
2.0 mm	RD	1.00						

	FE	0.57***	1.00					
	IT	0.69***	0.81***	1.00				
	CV	0.56***	0.59***	0.77***	1.00			
	SFC	-0.58***	-0.69***	-0.73***	-0.62***	1.00		
	BR	-0.71***	-0.75***	-0.83***	-0.71***	0.74***	1.00	
	BT	0.49***	0.50***	0.73***	0.64***	-0.76***	-0.60***	1.00

*ns=not significant, *=significant at P<0.05, **=significant at P<0.01, ***=significant at P<0.001. D- density; TFE-thermal fuel efficiency; IT-ignition time; CV-calorific value; SFC-specific fuel consumption; BR-burning rate; BR-water boiling time*

CONCLUSIONS

The interaction between density and some thermal characteristics such as thermal fuel efficiency, ignition time and calorific value investigated revealed positive and significant relationship except specific fuel consumption, burning rate that showed negative for all the four binder levels. The observed relationship between thermal fuel efficiency and relaxed density was positive and significant for all the compaction pressure and particles size levels (P<0.001).

The relationship between ignition time and relaxed density was positive and significant (P<0.001). The calorific value and relaxed density of briquettes demonstrated positive and significant correlation at all compaction pressure levels (P<0.001). The relaxed density of the briquette showed negative and significant correlation with specific fuel consumption (P<0.001). Relaxed density correlated positively and significantly with the observed water boiling time for all the pressure levels (P<0.001). A positive and significant relationship existed between thermal fuel efficiency and relaxed density (P<0.001). The interaction between the two parameters was positive and significant (P<0.001). The calorific value and relaxed density of briquettes demonstrated positive and significant correlation (P<0.005).The specific fuel consumption had negative and significant correlation with relaxed density. Relaxed density demonstrated positive and significant correlation with the observed water boiling time (P<0.001).

REFERENCES

[1] Adeniji TA, Sanni LO, Barimalaa IS, Teenkouano L, Hart AD. 2007. Antinutrients and heavy metals in new Nigerian Musa hybrid peels with emphasis on uitilization in livestock production. Fruit Journal, 63(2): 5-16.

[2] American Society of Agricultural and Biological Engineering (ASABE) 2003. Cubes, pellet and crumbles definitions and methods for determining density, durability and moisture content. St. Joseph, MI, America.

[3] Davies R.M. and Abolude, D.S. (2012).Ignition and burning rate of water hyacinth briquettes**.** Journal of Scientific Research & Reports 2(1): 111-120.

[4] Kaliyan N, Morey R. 2006. Densification characteristics of corn stover and switchgrass. Presented at the ASABE Annual International Meeting, July 9-12, 2006, Portland, or. ASABE Paper No 066174. ASAE, 2950 Niles Road, St. Joseph, MI 49085-9659, USA.

[5] Davies, R. M. and Davies, O.A. (2013). Physical and combustion characteristics of briquettes made from water hyacinth and phytoplankton scum as binder. *Journal of combustion*, Volume 2013, Article ID 549894, 7 pages**.**

[6] Olorunnisola AO. 2004. Briquetting of Rattan Furniture Waste. Journal of Bamboo and Rattan, 3 (2): 139-149.

[7] Bamgboye A, Bolufawi S. 2008. Physical Characteristics of Briquettes from Guinea corn (sorghum bi-color) Residue. Agricultural Engineering International: the CIGR Ejournal. Manuscript 1364.

[8] Saptoadi, H. (2008). The Best Biobriquette Dimension and its Particle Size. Asian J. Energy Environ, 9(3&4): 161-175.

[9] Kumar R, Chandrashekar N, Pandey KK. 2009. Fuel Properties and Combustion Characteristics of Lantana Camara and Eupatorium Spp. Current Science, 97(6): 930–935.

[10] Emerhi EA, 2011. Physical and combustion properties of briquettes produced from sawdust of three hardwood species and different organic binders. Advances in Applied Science Research, 2 (6):236-246.

[11] Jensen PA, Sander B, Dam-Johansen K. 2001. Pretreatment of straw for power production by pyrolysis and char wash. Biomass and Bioenergy, 20(2):431-446.

[12] Tumuluru JS, Sokhansanj S,. Lim CJX,. Bi L,. Anthony M, Staffan T, Sowlati T, Ehsan O. 2010. Quality of Wood Pellets Produced in British Columbia. Applied Engineering in Agriculture, 26(6): 1013–1020.

[13] Chin OC, Siddiqui KM. 2000. "Characteristics of some biomass briquettes prepared under modest die pressures, Biomass and Bioenergy, *18: 223–228.*

[14] Olorunnisola AO. 2007. Production of fuel Briquettes from Waste Paper and Coconut Husk Admixtures. Agricultural Engineering International: the CIGR Ejournal. Manuscript EE 06 066. Vol. 1X.

[15] Mailu, A.M. Oched, G.R.S., Gilonga, W. and Njoka, S.W. (2000). Water Hyacinth: An Environmental disaster in the Winam Gulf of Lake Victoria and its control, ODINAFRICA. In: Proceeding of the 1st 10BG Water hyacinth Working Group Pror–105. http:hdl.hardle.net/ 1834/1281 (Accessed December 14 2008).

[16] Lindsey, K. and Hirt, H.M. (2000). Use water hyacinth: Anamed, Winnenden, Germany, 114 pp.

[17] Olal MA. 2005. Handicrafts Prepared from water Hyacinth. In: Organic Resources Management in Kenya, perspectives and Guidelines, forum for Organic Resources Management and Agricultural Technologies (FORMAT).

[18] Sophie, D. (2006). A fart-Growing Plant Becomes mod furniture. In: Connecticut Cottage Gardens, cuttopes and Garden Publications, June 2006.

[19] Kitunda, J. (2006). Water Hyacinth-Double Edged, Appalachian State University, In: Human Flower project (Thursday, August 2006). Retrieved from http://wwwhumanflowerproject .com on 26th September, 2010.

[20] American Society for Testing and Materials (ASTM. E711-87) 2004: Standard test method for gross calorific value of refuse – derived fuel by the bomb calorimeter. Annual book of ASTM standard, 11.04.

[21] Onuegbu TU, Ekpunobi UE, Ogbu IM, Ekeoma MO, Obumselu FO 2011.. Comparative Studies of Ignition Time and Water Boiling Test of Coal and Biomass Briquettes Blend. IJRRAS, 7;153-159.

[22] Ndirika VIO. 1998. Development and Performance, Evaluation of a Baking Oven Using Charcoal as Source of Energy. Nigeria Journal of Renewable Energy, (12)1: 83-91.

[23] Kuti OA. 2010. Impact of Charred Palm Kernel Shell on the Calorific Value of Composite Sawdust Briquette. Journal of Engineering and Applied Sciences, 2 (1):62-65.

[24] Demirbas A, Sahin A. 1998. Evaluation of Biomass Residue Briquetting Waste Paper and Wheat Straw Mixtures. *Fuel Processing Technology*, 55: 175-183.

[25] Davies, R. M. and Davies, O.A. (2013). Physical and combustion characteristics of briquettes made from water hyacinth and phytoplankton as binder. *Journal of combustion*, Volume 2013, Article ID 549894, 7 pages**.**

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