CODEN (USA): IAJPBB **ISSN: 2349-7750**

INDO AMERICAN JOURNAL OF
PHARMACEUTICAL SCIENCES

http://doi.org/10.5281/zenodo.377016

Available online at: http://www.iajps.com ***Research Article***

INVESTIGATION ON COMBUSTION PROPERTIES OF COAL BRIQUETTE BLENDS FROM MANGONUT SHELLS AND EMPTY FRUIT BUNCHES

Eze - Ilochi Nkechinyere Olivia [1], Oti Wilberforce J.O. [2]
[1]Evangel University Akaeze, Ebonyi State, Nigeria.
[2]Ebonyi State University, Abakaliki, Ebonyi State, Nigeria.

Received: 28 December 2016 **Accepted:** 28 January 2017 **Published:** 28 February 2017

Abstract:
This work investigated the combustion properties of coal briquette blends from mangonut shells and empty fruit bunches. The coal briquette blends were prepared by blending pulverized mangonut shells and empty fruit bunches with coal, the ratio of coal to the biomass used were 100:0, 80:20, 60:40, 40:60, 20:80, 0;100. The mixture was treated with starch (which serves as binder) and calcium hydroxide (which serves as a desulphurizing agent) before briquetting. Proximate analyses and combustion properties (calorific value, ignition time and water boiling time) of the briquettes produced were analyzed and compared to that of coal briquette (100:0). ANOVA was used in the analysis of the differences between the mean results. The proximate analyses results showed 7.20% moisture content for coal, ranged from 7.40%-7.90% for coal empty fruit bunch (CE) briquettes and 6.18-7.12% for coal mango nut shell (CM) briquettes. Ash content of coal was 14.11% and ranged from 9.42%-7.40% for CE and 9.00%-5.41% for CM. The calorific values were 28.2MJ/kg, 24.7MJ/kg-21.8MJ/kg and 25.9MJ/kg-22.9MJ/kg for coal briquette, CE and CM briquettes respectively, and varied significantly ($p<0.05$). The results obtained showed that coal briquette blends from empty fruit bunches and mango nut shell can be used for small scale industrial and domestic cooking.

Keywords: *Coal briquette blends, empty fruit bunch, mangonut shell, water boiling test, ignition time.*

Corresponding Author:
Eze - Ilochi Nkechinyere Olivia,
Evangel University Akaeze,
Ebonyi State, Nigeria.

QR code

Please cite this article in press as Eze - Ilochi Nkechinyere Olivia and Oti Wilberforce J.O, ***Investigation on Combustion Properties of Coal Briquette Blends from Mangonut Shells and Empty Fruit Bunches****, Indo Am. J. P. Sci, 2017; 4(02).*

INTRODUCTION:

In the last few decades, researchers have been focusing on alternate fuel resources to meet the ever-increasing energy demand, and to avoid dependence on fossil fuel. Energy is the basic need for the economic development of a nation. In Nigeria, the demand for energy is higher than its supply and it is increasing day by day. The price of fossil fuel increases constantly that most Nigerians cannot afford it. They resort to the use of wood fuel, which encourages deforestation and other environmental problems associated with it such as global warming, soil erosion and extinction of wild life. Although fossil fuels play a key role in the global economic and political situations, their numerous challenges accounted for a shift to a more sustainable energy sources (Ismaila *et al*., 2013). Environmental and ecological problems are the major issues of concern associated with exploitation of these fuels. Another major challenge with these fuels is their unsustainability and projected depletion over the years.

Renewable energy sources are been sought for domestic and small scale industrial cooking in developing countries due to the fact that their non-renewable counterpart such as kerosene, cooking gas, etc, are not keeping up with people's demand (Ugwu *et al*., 2014). The main advantage of renewable sources of energy are its domestic origin, potential for reducing total dependence on oil and gas economy, energy security and waste management, job creation and source of revenues to the government and rural farmers. It also offers benefits of regional development and social structure, especially to developing countries like Nigeria (Ismaila *et al*., 2013). The use of biomass fuel has been proposed to be a good source of renewable energy for domestic and industrial purposes (Kuti and Adegoke, 2008). This is due to the fact that biomass is readily available in large quantities as wastes in Nigeria. Agriculture is the main occupation of most Nigerians and its activities generate so many wastes. Millions of tonnnes of various categories of biomasses are generated in Nigeria annually. Most of them if not properly disposed litter the environment, causing land, air and water pollution. It has been proposed that the conversion of these wastes through briquetting process will go a long way in reducing agricultural waste disposal problems. Briquetting is the agglomeration of fine particles by applying pressure to them and compacting them into various shapes. Briquetting of materials is useful as it enhances the volumetric calorific value up to 500-1500kcal/kg and density up to about 1000-1200 kg/m^3 (Wakchaure and Mani, 2009).

Recently, researchers showed that blending coal and biomass will give rise to a briquette with better combustion properties than biomass briquettes and also environmentally friendly (Zanjani *et al*., 2014; Lu *et al*., 2014; Yaman *et al*., 2001; Mahidin *et al*., 2013). This type of briquette is called coal briquette blends or bio-coal briquettes. Bio-coal briquette is a type of solid fuel prepared by compacting pulverized coal or coal fines, biomass, binder and a desulphurizing agent which fixes the sulphur in the coal to the ash. Although the combustion of coal emits oxides of sulphur, carbon and nitrogen, these are taken care of by the desulphurization agent Calcium hydroxide ($Ca(OH)_2$) which is incorporated into the mixture during briquetting. Calcium hydroxide forms $CaCO_3$ with CO_2 and $CaSO_3$ with SO_2. The $CaCO_3$ and $CaSO_3$ are left in the ash. Oxides of nitrogen dissolves in rain or moisture in the air to form hydrogen trioxonitrate (v) acid and are carried into the earth. In the soil, they react with mineral salts to produce trioxonitrate (v) and are assimilated into plant tissue as protein. Various biomass materials have been used in the production of coal briquette blends, e.g., coal-groundnut shell and coal-corn cob briquettes (Onuegbu *et al*., 2012), coal-corn stalk briquettes (Lu *et al*., 2014), coal-beet pulp briquettes (Zanjani *et al*., 2014).

Mango nut shell and empty fruit bunches are produced in large quantities in Nigeria. Mangoes *(Mangifera indica)* are the most important tropical fruit crop after bananas and plantain (FAO, 2011). Empty fruit bunches are also available as Nigeria is one of the largest producer of oil palm in West Africa (Ayodele, 2011). However, their potentials in the production of coal briquette blends/ bio-coal briquettes have not been adequately harnessed. Investigation of the combustion properties of their coal briquette blends are important in considering their suitability and potentials to produce energy that can be used for industrial and domestic process heat.

The aim of this work therefore was to analyze the combustion properties of coal briquette blends from mango nutshells and empty fruit bunches at different ratios of coal to biomass for their suitability as fuel for domestic and industrial heating. The need to protect our forest, seek for effective agro-waste management as well as provide an alternative source of energy which will reduce Nigerians' overdependence on oil and gas necessitated this work.

MATERIALS AND METHODS:

Preparation of materials: Onyeama coal was obtained from Nigerian Coal Corporation, Enugu. Mango nuts and empty fruit bunches were collected from Abakaliki metropolis, Nigeria, at different dumpsites and in farming communities where the wastes are produced in large quantities. The materials were sundried for two weeks to reduce their moisture content. The mango nuts were broken using a hammer to get the mango nutshell. The shells and empty fruit bunches were broken into very small sizes using cutlass, and then sundried for another one week. The cut mango nutshell and empty fruit bunches were pulverized using electrical milling machine and sieved using a standard sieve to obtain materials of particle size $\leq$ 3mm in diameter. The coal was broken into smaller pieces using a hammer, and then crushed to fine particles using an electrically operated hammer milling machine. The coal fine particles obtained were sieved using a standard sieve to obtain coal fines of size 1mm.

Formulation of the Briquettes:

The briquettes were formulated following the procedures of Onuegbu *et al.*, (2012) using a manually operated screw press. Coal briquette, coal briquette blends and biomass briquettes were formulated using different percentages of coal and biomass. The ratio of coal to biomass made were 100:0, 80:20, 60:40, 40:60, 20:80, 0:100. The quantity of calcium hydroxide used as the desulphurizing agent was 5% of the quantity of coal. The quantity of starch used as binder is 10% of the whole briquette as shown in Table 1.

Table 1: Briquette formulation

	Ratio of coal to biomass					
Materials	**100:0**	**80:20**	**60:40**	**40:60**	**20:80**	**0:100**
Coal (g)	300	240	180	120	60	0
Biomass(g)	0	60	120	180	240	300
Starch (g)	30	30	30	30	30	30
$Ca(OH)_2$(g)	15	12	9	6	3	0

Procedure: 100g of starch was mixed with 100ml of water to make a paste of it. 400ml of water was put to boil in a container. The boiling water was added into the starch paste and mixed thoroughly to get the starch gel. While the starch gel was still warm, 300g of the materials and the $Ca(OH)_2$ was gradually added and mixed properly using a stirring stick, until a homogenous mixture was obtained. The mixture was fed into the moulds of the briquette press. Pressure was applied on the materials to form the briquettes. The pressure of the press is 12.3kpa and the dwell time was 2mins. The briquettes were sundried until their moisture content significantly decreased and the briquettes became very stable. The same pressure procedure was applied to all the briquettes. Plate 1 and 2 show the briquette press used and the briquettes produced respectively.

Plate 1: The screw press

Plate 2: The briquettes produced.

Determination of Combustion Characteristics of the Briquettes

Proximate analyses of the briquettes were carried out following the procedures of ASTM E1871 -82, (2006) for moisture content, ASTM E872- 82, (2006) for volatile matter, and ASTM E1755- 01, (2007) for ash content. The fixed carbon content was determined by difference according to the formula proposed by Garcia *et al.*, (2012).

Calorific value was determined using an Oxygen Bomb Calorimeter (Model XRY-IA). Ignition time was determined following the procedures described by Davies and Abolude, (2013). Each briquette was placed on a gauze which was placed on a tripod stand. A Bunsen burner was used to ignite the base of the briquette from under the gauze. The Bunsen burner was adjusted to blue flame and it was also ensured that the whole of the bottom surface of the briquette was ignited simultaneously. The burner was left to burn until the briquette was well ignited and had entered into its steady state burn phase. A stopwatch was used to note the time the base of the briquette ignites. The water boiling time was determined following the procedures of Kuti, (2009). 500ml of water was measured into a pot with cover. Each briquette sample (500g) was weighed, put in the briquette stove and ignited. Immediately, the pot containing the water was placed on the stove and the time t_1 noted. At the intermediate phase, i.e., when boiling was first noticed, the boiling time t_2 was recorded. The water boiling time calculated using the relation: t_2-t_1

Analysis of variance (ANOVA) was used for the statistical analysis of the generated at $p<0.05$.

RESULTS AND DISCUSSION:

The different briquettes comprising of varying quantities of coal and biomass were labeled as follows: The briquette comprising of coal : biomass in the ratio of 100: 0 (i.e. the coal briquette) was labeled C. The briquettes prepared from coal and mango nut shell (CM) in the ratios of 80:20. 60:40, 40:60, 20:80 were labeled CM_1, CM_2, CM_3, CM_4 respectively, while those from coal and empty fruit bunches (CE) in the ratios of 80:20. 60:40, 40:60, 20:80 were labeled CE_1, CE_2, CE_3, CE_4 respectively. Briquette of 0:100 coal to mango nut shell was labeled M_5, while that of 0:100 coal to empty fruit bunch was labeled E_5.

Table 2: Proximate analyses results of the briquettes produced

Briquettes	Moisture content (%)	Ash content (%)	Volatile matter(%)	Fixed carbon content (%)
C	7.20 ± 0.26	14.11 ± 0.60	31.31 ± 0.17	46.38 ± 0.35
CE_1	7.40 ± 0.16	9.42 ± 0.26	42.15 ± 0.85	41.03 ± 0.44
CE_2	7.80 ± 0.18	8.19 ± 0.05	47.00 ± 0.44	37.01 ± 0.23
CE_3	7.90 ± 0.08	7.84 ± 0.23	54.00 ± 0.26	30.26 ± 0.14
CE_4	7.90 ± 0.32	7.40 ± 0.94	61.25 ± 0.59	24.45 ± 0.92
E_5	7.80 ± 0.21	5.21 ± 0.17	71.45 ± 0.37	15.54 ± 0.42
CM_1	6.18 ± 0.06	9.00 ± 0.16	47.00 ± 0.47	36.82 ± 0.13
CM_2	6.16 ± 0.27	8.84 ± 0.36	50.13 ± 0.44	38.87 ± 0.45
CM_3	6.63 ± 0.48	6.98 ± 0.32	59.42 ± 0.26	25.97 ± 0.87
CM_4	7.12 ± 0.07	5.41 ± 0.10	63.50 ± 0.17	22.92 ± 0.18
M_5	7.40 ± 0.18	4.62 ± 0.46	74.II ± 0.10	13.87 ± 0.25

Table 2: showed the results of the proximate analyses of the briquettes.

Moisture Content: Moisture content of the briquettes increased as the biomass load increases. The moisture content of CE briquettes (7.40% - 7.90%) are higher than that of CM briquettes (6.18% -7.12%). In each case, the E_5 (7.80%) and M_5 (7.40%) have the highest moisture content values. C has 7.20%. The moisture content of the briquettes did not exceed 10%, showing that they are good for storability and combustibility as recommended by Mills (Mills, 1998). The increase in moisture content as biomass load increases may be attributed to the fact that biomass materials contain inherent water molecules and therefore increased the moisture content of the briquettes.

Ash Content: The quantity of ash produced decreased with increasing biomass load. The ash content of CE briquettes ranged from 9.42%-7.40%, and had higher values than CM briquettes which ranged from 9.00% - 5.41%. The E_5 (5.21%) and M_5 (4.62%) had the lowest ash content values in each case, while C had the highest value (14.11%). The decrease in ash content as the biomass load increased is because coal contains higher proportion of ash forming elements (Na. K, Mg) than the biomass materials. The ash content reported is low, implying that the briquettes will have better thermal utilization (Akowuah *et al.,* 2012). The ash content values obtained did not exceed 15%, implying that they will not cause an increase in the combustion remnant in the form of ash (Sotannde *et al*., 2010).

Volatile Matter: Volatile matter content increased as the biomass load increases, with the CM briquettes having higher values (47.00% - 63.50%) than the CE briquettes (47.15% - 61.25%). The C had 31.31%. Also, E_5 (71.45%) and M_5 (74.11%) have the highest values in each case. This finding is in line with that reported by Akowuah *et al.,* (2012), that biomass generally contains high volatile matter content.

Fixed Carbon: The fixed carbon content decreased as the biomass load increases. CE briquettes had values ranging from 41.03% - 24.45%, while CM briquettes had values in the range of 36.82% - 22.92%. E5 (15.54%) and M5 (13.87%) have the lowest values, while C has the highest values 46.38%. The high fixed carbon content of C is due to its mineral composition. As coal is replaced with biomass in CM and CE briquettes, fixed carbon content decreased.

Table 3: Combustion properties of the briquettes

Briquettes	Mean calorific value (MJ/kg)	Mean ignition time (seconds)	Mean water boiling time (mins)
C	28.2	27.54	13.52
CE_1	24.7	20.40	15.54
CE_2	23.5	19.10	16.56
CE_3	22.1	18.00	18.09
CE_4	21.8	15.03	18.40
E_5	19.8	13.04	19.52
CM_1	25.9	22.17	14.55
CM_2	24.5	21.49	15.43
CM_3	23.4	20.05	16.58
CM_4	22.9	16.05	17.16
M_5	21.9	13.43	18.46
p	0.000	0.000	0.000

Table 3 showed the calorific value, ignition time and water boiling time of the briquettes produced.

Calorific Value: The calorific value results showed that C had the highest calorific value compared to the other briquettes. The values obtained for CM briquettes (25.9MJ/kg - 22.9MJ/kg) are higher than those obtained for CE briquettes (24.7MJ/kg – 21.8MJ/kg). The E_5 had 19.8MJ/kg and was lower than M_5 21.9MJ/kg. The calorific values also decreased with increased biomass load, this is due to the fact that biomass materials have low calorific value compared to coal. The mean values obtained were significantly different at all ratios of biomass load and biomass type, $p<0.05$. The values obtained are also comparable to those obtained by Wilaipon, (2007), 14.1MJ/kg for maize cob briquettes and Ivanov *et al.*, (2003), 24.27MJ/kg for lignite with bio-binder.

Ignition Time: Ignition time decreased as biomass load increases, with C having the highest values, (27.54seconds). The CM briquettes had values ranging from 22.17seconds – 16.05 seconds, and are higher than CE briquettes with values 20.40 seconds - 15.03 seconds. The E_5 and M_s briquettes had the lowest values in each case, 13.04 seconds and 13.43 seconds respectively. The mean ignition time for the briquettes were significantly different, $p<0.05$, implying that the biomass type and ratio had effects on the ignition time of the briquettes. The shorter ignition time of CE and CM briquettes compared to coal can be as a result of the high volatile matter content of biomass materials present in them.

Water Boiling Time: Water boiling time results showed 13.52 mins for C, 15.54 mins -18.40 mins for CE, 14.55 mins -17.16 mins for CM, 19.52 mins for E_5 and 18.46 mins for M_5. Biomass ratio and type significantly influenced the water boiling time of the briquettes, $p=0.000$, ($p<0.05$). This showed that the water boiling time increased with increase in biomass load, and is as a result of decrease in calorific value of the briquettes as the biomass load increases. As a result, the heat and energy released by the fuel during heating reduced, increasing the time required to boil water. This findings is in agreement with those observed by Ikelle and Ogah, (2014) and Onuegbu *et al.*, (2012).

CONCLUSION:

The combustion properties of the briquettes depended largely on their calorific values and to an extent on their moisture content, ash content and volatile matter content. The coal briquette blends had calorific values comparable to that of the coal briquette. Therefore, they can provide sufficient heat for both domestic and industrial heating. Moreover, they are more environmental friendly than the conventional coal briquette. They can comfortably replace coal briquettes for domestic cooking and small scale industrial heating. Empty fruit bunches and mango nut shell can therefore be used in coal briquette blend manufacture, thereby putting them to good use, as well as solve the problem of environmental degradation caused by burning of such wastes.

REFERENCES:

Akowuah , J.O., Kemausuor, F. and Mitchual, S., (2012), Physico- chemical Characteristics and Market Potential of Sawdust Charcoal Briquette, International Journal of Energy and Environmental Engineering, 3: 20.

Annual Book of ASTM Standards, (2006), Standard Test Method for Moisture in the Analysis of Particulate Wood Fuels, E1871-82

Annual Book of ASTM Standard, (2006), Standard Test Method for Volatile Matter in the Analysis of Particulate Wood Fuels, E872-82

Annual Book of ASTM Standards, (2007), Standard Test Method for Ash in Biomass, E1755-01

Ayodele Thompson, (2011), African Case Study, Palm Oil and Economic Development in Nigeria and Ghana. Recommendations for the World Bank‘s 2010 Palm Oil Strategy, pp 1-6.

Davies, R.M. and Abolude, D.S., (2013), Ignition and Burning Rate of Water Hyacinth Briquettes, Journal of Scientific Research and Reports 2(1): 111-120.

FAO, (2011), FAOSTAT, Food and Agricultural Organization of the United Nations

Garcia, R., Pizarro, C., Lavin, A.V. and Bueno, J.L., (2012), Characterization Of Spanish Biomass Waste For Energy Use, Bioresources Technol, 103, 249-258.

Ikelle, I.I and Ogah, S.P.I., (2014), Determination of the Heating Ability of Coal and Corncob Briquettes, Journal of Applied Chemistry, 7(2): 77-82.

Ismaila, A., Zakari, I., Nasiru, R., Tijjani, B.I., Abdullahi, I., and Garba, N. N., (2013), Investigation on Biomass Briquettes as Energy Source in Relation to Their Calorific Values and Measurement of Their Total carbon and Elemental Contents For Efficient Bio-fuels Utilization, Advances in Applied Science Research, 4(4): 303-309

Ivanov, I.P., Sudakova, I.G. and Kuznetsov, B.N., (2003), Manufacture of Briquetted and Granulated Fuels from Lignite with Biobinders and Heated Die, Chemistry For Sustainable Development, pp 847-85

Kuti O. A., (2009), Performance of Composite Sawdust Briquette Fuel in a Biomass Stove Under Simulated Condition, AU J. T, 12(4): 284-288

Kuti O.A. and Adegoke, C. O., (2009), Comparative Performance of Composite Sawdust Briquette With Kerosene Fuel Under Domestic Cooking Conditions, AQ.J.T 12: 57-61

Lu G, Cheng F and Li J, (2014), Enhancement of Coal Briquette Quality Through Corn Stalk Blending and Binder Optimization, Environmental Progress and Sustainable Energy, 34(2): 613-618.

Mills, J. E, (1998), Binders for Coal Briquettes, U S Geological Survey, Bulletin 343, pp 5- 59.

Ogwu, I. Y., Tembe, E. T. and Shomkegh, S. A., (2014), Comparative Analysis of Calorific Value Of Briquettes Produced From Sawdust Particles of Daniella Oliveri and Afzella Africana Combination at Binary and Tertiary levels with Rice Husk, Journal of Research in Forestry, Wildlife and Environmental Research, 6:13-21.

Onuegbu, T. U., Ilochi N.O. and Okafor, I., (2012), Preparation of Environmentally Friendly Bio- coal Briquette from Groundnut Shell and Maize Cob Biomass waste. Comparative Effect of Ignition Time and Water Boiling Studies, Current Research in Chemistry 4: 110- 118

Sotannde, O.A., Oluyeye, O.A. and Abah, G.B., (2010), Physical and Combustion Properties of Charcoal Briquettes from Neem Wood Residues, International Agrophysics 24: 189-194

Ugwu, K.E. and Agbo, K.E., (2011), Briquetting Of Palm Kernel Shell, Journal Of Applied Science And Environment Management, 15 (3): 447-450.

Wakchaure, G.C. and Mani Indra, (2009), Effect of Binders and Pressures on Physical Quality of Some Biomass Briquettes, Journal of Agricultural Engineering, 46(4): 24- 30.

Wilaipon, P., (2007), Physical Characteristics of Maize Cob Briquette Under Moderate Die Pressures, Am. J. Applied Science, 4: 995-998.

Zanjani, N. G., Zarringhalam, M. A. and Dorosti, S., (2014), Physical and Chemical Properties of Coal Briquettes From Biomass- Bituminous Blends, Journal of Petroleum and Coal, 56(2): 188-195.