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Data Article

Dataset on the performance characteristics of briquettes from selected agricultural wastes using a piston-type briquetting machine

M.A. Waheed[a,c], O.A. Akogun[b], C.C. Enweremadu[c,*]

[a] Department of Mechanical Engineering, College of Engineering, Federal University of Agriculture, Abeokuta, P. M. B. 2240 Abeokuta, Nigeria
[b] Agricultural Mechanization and Sustainable Environment Programme, Centre of Excellence in Agricultural Development and Sustainable Environment, Federal University of Agriculture, P. M. B. 2240 Abeokuta, Nigeria
[c] Department of Mechanical Engineering, College of Science, Engineering, and Technology, University of South Africa, Science Campus, FL 1709, South Africa

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A B S T R A C T

Densification of agricultural wastes for briquette production has considerable potential to meet the growing energy demand and contribute towards a safe environment worldwide. The datasets contained in this paper are the performance characteristics of raw and torrefied briquettes produced from sawdust (SD), cassava peels (CP), cornhusk (CH), and their blends using a developed piston-type briquetting machine. The physicomechanical, chemical, structural, and combustion indices including the kinetic parameters, were determined using standard methods. The result obtained show that each briquettes sample has the infrared transmittance of C–H, OH, C–O, and C=C with the SD sample having the highest and CP, the lowest. The feedstock mixture and increase in torrefaction temperature enhance the physicomechanical properties of the briquettes through water preconditioning. The combustion characteristics show that the torrefied briquettes and their blends could be co-fired with coal, and are well suited for heating applications and reduce environmental pollution. The activation energy, pre-exponential factor, and R^2 values of the briquettes ranged between 39.70–60.76 kJ/mol, 5.52–9.17 min^{-1}, and 0.95–0.98, respectively. The data provided

* Corresponding author.
E-mail address: enwercc@unisa.ac.za (C.C. Enweremadu).

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in this paper will therefore be useful for energy enthusiasts and coal engine design, and assist in choosing the appropriate briquette blends with increased calorific value for heating applications.

Specifications Table

Subject	Engineering
Specific subject area	Biofuels, Biomass Conversion
Data format	Raw, Analyzed, Filtered
Type of data	Tables and Figures
Data collection	Each feedstock including the cornhusk (CH), sawdust (SD), and cassava peels (CP) was processed by drying (CH was dried in an oven at 104.5 °C for 5 h; CP and SD were sun-dried for one month and two weeks, respectively), milling, sieving to particle sizes less than 1.18 mm, torrefied (at 200, 250, and 300 °C), and water preconditioned using standard procedures. Each of the raw and the torrefied feedstocks was thoroughly mixed in pairs (i.e., CH/CP; CH/SD; SD/CP) at the ratio of 100/0, 90/10, 70/30, 50/50, 30/70, 10/90, and 0/100 (w/w). The samples were separately compressed with a piston-type briquetting machine developed by the research team for briquette production, and the performance characteristics of the wet and sun-dried briquettes were thereafter carried out according to standard procedures.
Data source location	Central Workshop of the College of Engineering, Federal University of Agriculture, Abeokuta, Nigeria (FUNAAB) (7° 11′ 34.4″ N, 3° 27′ 14.2″ E), the Chemical Sciences Laboratory, University of Johannesburg, South Africa (26° 10′ 60.00″ S, 27° 59′ 33.59″ E), and the iNanoLab, University of South Africa, Florida Campus (26° 9′ 2.52″ S, 27° 54′ 9.5″ E).
Data accessibility	Data identification number: doi:10.17632/hsfbtymdmf.1 Direct URL to data: https://data.mendeley.com/datasets/hsfbtymdmf/1
Related research article	Waheed MA, Akogun OA, Enweremadu CC (2023). Influence of feedstock mixtures on the fuel characteristics of blended cornhusk, cassava peels, and sawdust briquettes. Biomass Conversion and Biorefinery, 2023: 1–16. https://doi.org/10.1007/s13399-023-04039-6.

Value of the Data

- The dataset on the physicomechanical properties of the briquettes produced through water preconditioning is useful for the analysis of the strength enhancement of the raw briquettes and their blends through torrefaction.
- The dataset of the proximate properties through fixed carbon (FC) content, volatile matter (VM), ash content (AC), and moisture content (MC) for torrefied briquettes presents a potential of good burning for heating applications over the raw samples and their blends.
- The dataset is useful for the prediction of the calorific value (CV) enhancement of briquette through torrefaction pretreatment, translating to optimum performance in several domestic and industrial applications.
- The thermogravimetric analysis (TGA) curves show that the CP and SD briquettes, respectively have the lowest and highest weight loss. Moreover, the increased proportion of SD in CP/SD and CH/SD briquette samples led to a decrease in their residual weight.
- Through EDS, Ca, Si, and K are the major briquette agglomeration elements that play the most significant role during the thermal process of CP, CH, and SD.

• The dataset established that some blends of the torrefied feedstock meet the standard values of combustion indices for co-firing in coal thermal engines.

1. Data Description

The quality of the briquettes produced from the cassava peels, cornhusk, sawdust, and the blends of these feedstocks in pairs at different torrefaction temperatures and feedstock mixture ratios were experimentally determined and presented in this text. The direct URL of the data is presented for data accessibility.

The Excel file named “physicomechanical properties” in the dataset presents the data on the compressed density (CD), relaxed density (RD), relaxation ratio (RR), compressive strength (CS), durability index (DI), and water resistance index (WRI) for CH, CP, SD, and their blends in pairs as CH/SD, CH/CP, and CP/SD at 100/0, 90/10, 70/30, 50/50, 30/70, 10/90, and 0/100 blending ratio. The properties are useful for the determination of the strength attributes of the briquette fuel.

The Excel file named “proximate characteristics” presents the data on the volatile matter (VM), ash content (AC), fixed carbon (FC) content, and moisture content (MC) of the feedstocks and their blends with the same compositions as used for the physicomechanical properties. The quantities are relevant for the evaluation of the fuel properties of the briquette samples.

The Excel file named “combustion indices” presents the data on the combustibility index (CI), fuel ratio (FR), and volatile ignitability (VI) of the different briquette samples used for assessing the suitability of a briquette fuel in a coal engine. The data are provided for the different briquette samples and their blends.

The Excel file named “TGA” presents the data on the weight loss against the temperature of each briquette sample at a constant rate when subjected to a pyrolysis temperature. The information on the heat flow for the CH, SD, and CP briquettes, and their CH/SD, CH/CP, and CP/SD blends at different ratios was also presented.

The “SEM” folder contains the microstructural attributes of the briquettes samples. The subfolder namely “CH100” contains TIF files tagged 1, 2, 3, and 4 representing the SEM magnification at 55x, 100x, 200x, and 400x, respectively. Other subfolders contain similar data for briquette samples CP100, SD100, and their blends at the SEM magnification of 55x, 100x, 200x, 400x, 1.00kx, and 1.00kx, respectively.

The information on the FTIR of the CH, SD, CP, and blends is presented in the “FTIR” folder. The data give the details of the functional groups of each briquette sample.

The elemental characteristics which are used to evaluate the carbon content (CC), hydrogen content (HC), and nitrogen content (NC) of the briquette samples are represented in the file entitled “CHNO.pdf”. The summary presents the average values of the elemental characteristics of each briquette sample taken twice.

The feedstock loading time, compaction time, briquette ejection time, and the total production time in percentage for the production of briquettes are presented in Table 1. The measurement of the briquette’s dimensions was done using a digital vernier caliper as shown in Fig. 1. The mass yield of 100 g of each feedstock when subjected to torrefaction is presented in Table 2.

Table 1
Components and time for briquette production.

Components	Time (secs)	Total production time in%
Feedstock loading time	249	41.5
Feedstock compaction time	300	50.0
Briquette ejection time	51	8.5
Total	600	100.0

Adapted from Akogun and Waheed [1].

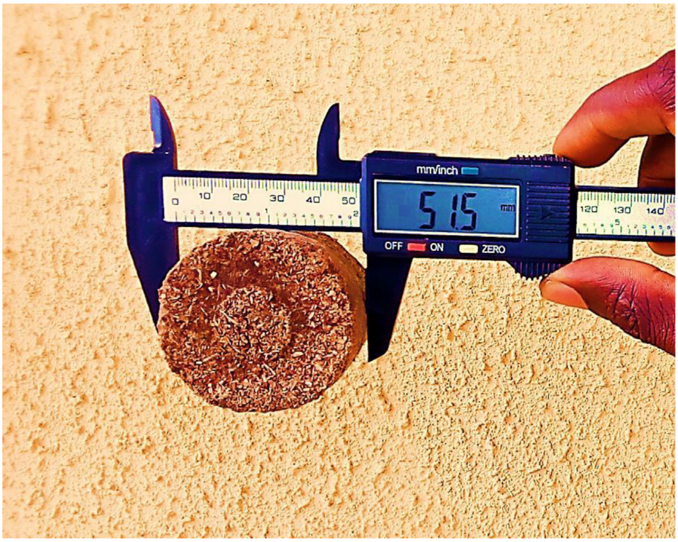

Fig. 1. Measurement of briquette's dimensions using a digital vernier caliper.

Table 2
Mass yield of 100 g feedstock when subjected to torrefaction.

Temperature (°C)	SD (g)	CH (g)	CP (g)
Raw	100.00	100.00	100.00
200	92.86	88.61	96.29
250	86.65	76.13	83.21
300	49.33	55.36	58.92

Adapted from Akogun and Waheed [1].

The calorific value (CV) which is the measure of the energy released by the briquettes at complete combustion is presented in Table 3.

Table 3
Calorific value (MJ kg^{-1}) of the briquette samples.

Feedstock	Raw	200 °C	250 °C	300 °C
CH (100%)	12.27	13.29	15.19	16.23
SD (100%)	12.70	13.90	15.72	16.95
CP (100%)	11.67	13.19	13.82	14.92
Cornhusk and sawdust				
CH/SD (90/10)	12.43	14.37	16.02	19.90
CH/SD (70/30)	12.78	14.44	16.94	21.24
CH/SD (50/50)	13.47	16.43	17.48	21.54
CH/SD (30/70)	13.04	15.79	17.23	22.12
CH/SD (10/90)	13.12	15.53	17.09	22.78
Cornhusk and cassava peel				
CH/CP (90/10)	13.34	15.58	17.74	19.31
CH/CP (70/30)	13.05	15.44	16.44	18.94
CH/CP (50/50)	12.66	15.41	16.30	18.78

(*continued on next page*)

Table 3 (*continued*)

Feedstock	Raw	200 °C	250 °C	300 °C
CH/CP (30/70)	12.41	15.14	15.89	18.42
CH/CP (10/90)	12.29	14.06	15.51	17.89
Sawdust and cassava peel				
SD/CP (90/10)	12.96	14.12	15.89	20.94
SD/CP (70/30)	12.91	13.99	15.59	20.36
SD/CP (50/50)	13.74	15.21	16.60	19.89
SD/CP (30/70)	12.61	13.29	14.73	19.26
SD/CP (10/90)	12.17	13.36	14.00	18.44

The EDS presented in Table 4 reflects the inorganic attributes of the briquettes such as the potassium, silicon, chlorine, magnesium, calcium, phosphorus, sulfur, aluminum, iron, and tin content.

Table 4
EDS analysis of the briquette samples.

Feedstock	K	Si	Cl	Mg	Ca	P	S	Al	Fe	Ti
CH	1.3	0.3	0.2	0.2	0.2	0.1	0.1	–	–	–
CP	1.3	0.2	–	0.5	2.5	0.1	0.2	0.2	–	–
SD	0.5	–	–	–	0.4	–	–	–	–	–
CH/CP (30/70)	0.9	0.2	–	–	0.2	–	–	0.1	–	–
CH/CP (50/50)	1.3	1.2	0.2	0.3	0.4	0.3	0.2	0.3	–	–
CH/CP (70/30)	0.5	1.1	0.1	0.1	0.2	0.1	0.1	0.4	0.3	–
CH/SD (30/70)	0.6	0.1	0.1	–	0.3	0.1	–	–	–	–
CH/SD (50/50)	0.6	0.2	0.1	–	0.2	0.1	–	0.1	–	–
CH/SD (70/30)	0.9	0.3	0.1	–	0.2	0.1	–	0.1	–	–
SD/CP (30/70)	1.2	0.5	0.1	0.2	1	0.1	0.2	0.4	0.5	–
SD/CP (50/50)	1	1.3	–	0.3	0.9	0.1	0.1	1.2	0.9	0.1
SD/CP (70/30)	0.9	0.3	–	–	0.7	–	–	0.2	0.7	–

Note: K-Potassium, Si-Silicon, Cl-chlorine, Ca-Calcium, Mg-Magnesium, P-Phosphorus, S-Sulphur, Al-Aluminum, Fe-Iron, Ti- Tin.

The kinetic parameters contain in Table 5 provide data on the activation energy and pre-exponential factor required for the design and optimization of the biomass combustion system for heating applications.

Table 5
Activation energy and pre-exponential factor of the briquettes using the Coats-Redfern method.

Sample	Activation energy, E_a (kJ mol^{-1})	Pre-exponential factor ln (A) (min^{-1})	Coefficient of determination R^2
CH (100%)	47.62	7.60	0.97
SD (100%)	39.70	9.17	0.95
CP (100%)	60.76	5.52	0.98
CH/SD (30/70)	46.97	7.95	0.98
CH/SD (50/50)	47.45	7.79	0.96
CH/SD (70/30)	43.97	8.25	0.97
CH/CP (30/70)	44.28	8.41	0.96
CH/CP (50/50)	48.26	7.59	0.96
CH/CP (70/30)	45.11	8.31	0.96
CP/SD (30/70)	43.45	8.64	0.94
CP/SD (50/50)	46.10	8.18	0.97
CP/SD (70/30)	43.47	8.62	0.96

Adapted from Waheed et al. [2].

The parameters for the water boiling performance test including burning rate (BR), specific fuel consumption (SFC), water boiling time (WBT), and thermal efficiency (TE), determine the performance of the fuel sample during water boiling. Meanwhile, the SFC, BR, and WBT for the CH and SD briquettes are presented in Figs. 2-4.

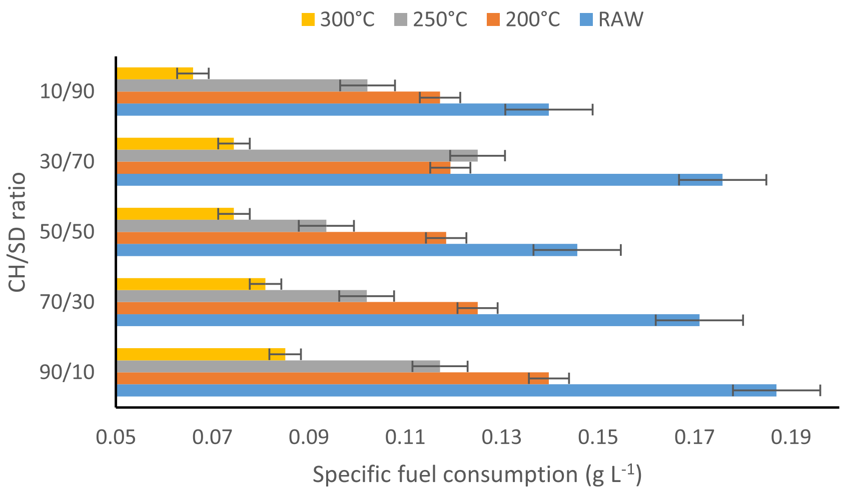

Fig. 2. SFC of CH and SD briquettes (Adapted from Waheed and Akogun [3]).

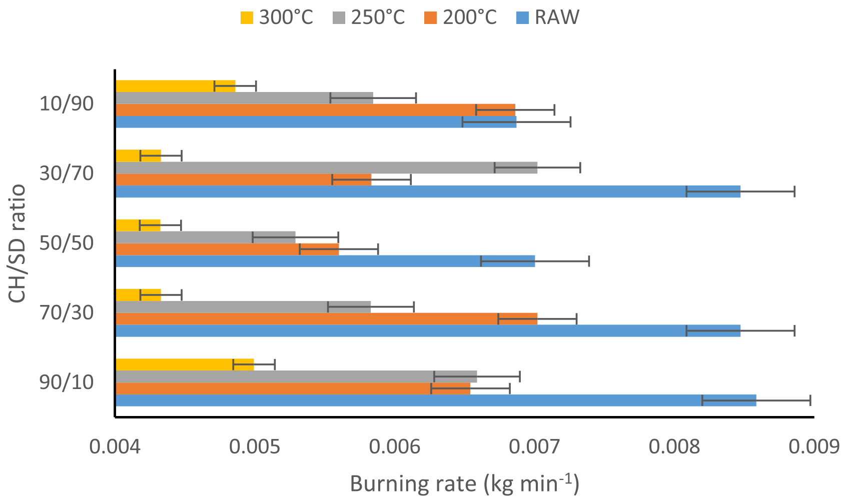

Fig. 3. BR of CH and SD briquettes (Adapted from Waheed and Akogun [3]).

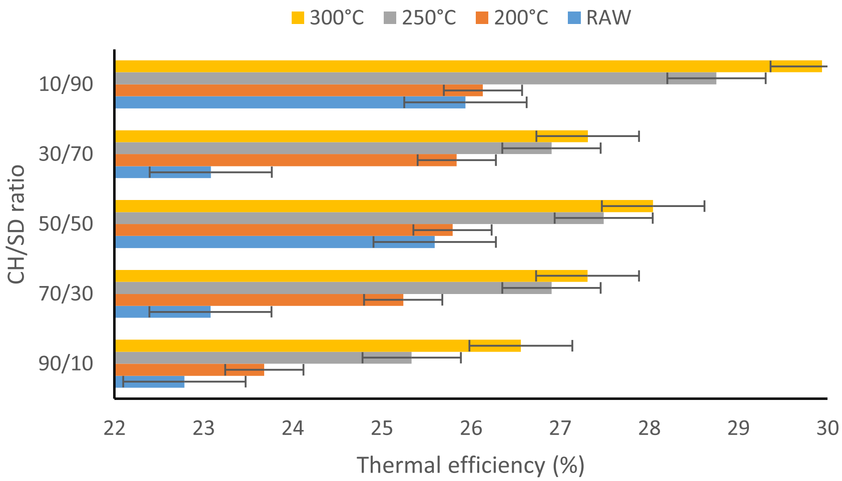

Fig. 4. Thermal efficiency of CH and SD briquettes (Adapted from Waheed and Akogun [3]).

2. Experimental Design, Materials and Methods

Sawdust, cornhusk, and cassava peel wastes were used in this research. This is because they are abundant in Southwestern Nigeria. These wastes constitute a nuisance, unpleasant smell, health challenge and ultimately waste useful energy. The cornhusk (CH) was sourced from the research farm of the Federal University of Agriculture, Abeokuta (FUNAAB), Nigeria, while cassava peels (CP) and sawdust (SD) were obtained in the vicinity of Abeokuta (7° 11′ 34.4″ N, 3° 27′ 14.2″ E) in Southwestern Nigeria. The cornhusk samples were sorted out from impurities and then dried in an oven at 104.5 °C for 5 h. At this period, the cornhusk residue becomes crispy making it ready and easier to mill. The cassava peel sample was sun-dried for one month until the required moisture content was obtained. Unwanted materials were removed from the cassava peels before size reduction was done. The sawdust on the other hand was sun-dried for 2 weeks. Each of the feedstocks was milled to particle sizes below 1.18 mm and then kept in a desiccator for further analysis. The cassava starch in its gelatinous state was used as the binder. The variables and levels of the independent factors were fixed based on the information from trial experiments and literature [4–6]. The independent variables used for the study were two feedstock mixtures (CP/SD; CH/SD; CP/CH) at the ratio of 100/0, 90/10, 70/30, 50/50, 30/70, 10/90, and 0/100 and a process factor which was the torrefaction condition of feedstocks (raw, 200, 250 and 300 °C), while the responses were the physicomechanical, proximate, elemental, EDS, CI**,** SEM, FTIR, TGA, and WBT. The feedstocks were subjected to torrefaction to improve their performance index by loading them through some thin-walled crucibles containing 100 g of each sample into a furnace which was heated at the rate of 10 °C/min for 60 mins until the desired temperature between 200 and 300 °C was achieved for each test. The torrefied samples were thereafter water preconditioned. The hydrogen bonding capability provided by the water preconditioning enhances the plasticity of the torrefied products and decreases energy consumption [7]. The three samples each in their raw and torrefied state were blended in pairs with one another (i.e., cornhusk and cassava peel; cornhusk and sawdust; sawdust and cassava peel) at the ratios of 100/0, 90/10, 70/30, 50/50, 30/70, 10/90 and 0/100. These blends were thereafter mixed homogenously with the 20% of binder to each feedstock blend. This was done to determine the influence of the binder over the characteristics of the briquettes to be produced and to obtain a uniformly blended mixture. The mixture was then weighed and compressed into a 15 MPa briquetting machine at a residence time of 5 min. A pressure of 15 MPa was used to achieve improved physico-mechanical properties of briquettes while the dwell time of 5 min was used to give room for better briquette formation and to also allow water to drain. The compressed density was determined immediately after ejection using a digital weighing balance and a digital caliper for mass and volume determination (Fig. 1), respectively while other physico-mechanical characteristics such as the relaxed density, relaxation ratio, durability index, compressive strength, and the water resistance index of the briquettes were determined after sun drying for 3 weeks.

Other performance index of the briquette samples such as the calorific value, which is a quantity used to evaluate the energy released by the briquette at complete combustion, was determined using a Gallenkemp XRY-1A model bomb calorimeter [8–9]. The briquette was also subjected to proximate analysis including ash content (AC), moisture content (MC), and volatile matter (VM) while the fixed carbon (FC) content was calculated by subtracting the sum of the MC, AC, and VM content from 100% [5,6]. The combustion indices such as the fuel ratio, combustibility index, and volatile ignitability were studied to determine the applicability of produced briquettes as solid fuels in a coal engine [8,10–11]. The elemental analysis was studied with Flash 2000 CHNS/O Elemental Analyzer (Thermo Fisher Scientific, USA; Serial No. 2009.F0002) [8,12]. The morphology of the samples and the trace element present in the fuel were obtained using a typical SEM coupled with an Oxford Energy Dispersive X-Ray Detector (Czech Republic) model 51-XMX1010 to present the microporous and mesoporous distributions of the briquette samples at different magnification. A Perkin Elmer Frontier FTIR Spectrometer 3 model was used to study the FTIR spectra and functional group of the samples. The thermogravimetric analysis was determined in line with Bai et al. [12]. The specific fuel consumption, burning rate, and thermal efficiency of the briquette samples were determined during the water boiling test [3,13]. Meanwhile, a non-isothermal evaluation of the kinetic parameters (activation energy and pre-exponential factor) of the samples was carried out in line with Coats and Redfern [14].

Ethics Statement

The authors did not conduct human or animal studies.

Limitations

Not applicable.

Data Availability

Data for publication (Original data) (Mendeley Data).

CRediT Author Statement

M.A. Waheed: Conceptualization, Methodology, Writing – review & editing; **O.A. Akogun:** Methodology, Writing – review & editing; **C.C. Enweremadu:** Conceptualization, Project administration.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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