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Research Paper

Physicochemical and Thermal Properties of Rice Husk Char From Wacot Rice Mills Argungu, For Biofuel Production And Sustainable Waste Management.

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ABSTRACK
The study was conducted to determine the physical, chemical and some thermal properties of rice husk char as one of the largest waste product produced by WACOT rice mills in Argungu, kebbi State Nigeria. Rice husk char sample was collected for three months August, September and October. The samples were analyzed for their chemical and other elemental compositions at chemistry Laboratory of UsmanuDanfodio University Sokoto, Nigeria. Thermal energy characteristics of the char for biofuel production were determined after the sample was converted into Briquettes. The parameters investigated include heating value, ignition time, burning rate, and specific fuel consumption. Water boiling time and time taking by the Samples to burn to ashes were also determined. The results for chemical and elemental analyses show the presence of low percentage carbon contentat the range of 16-8 for the entire sample. Other chemical components of the char detected were P,K,Ca, Mg and Na which may be very vital for other applicationsof biochar. The result for thermal characteristics of briquette show that all briquettes sample produced have higher ignition rate ranging from 1- 1.2 minutes and low burning rate that range from 0.12 -0.069. All samples show a very low heating value of 0.66, 066 and 0.53. Other
Thermal characteristics analyzed such moisture content, ash content; durability test, water absorption and resistance are within the ASTM standard. The results confirmed that, the fuel briquettes made from WACOT RHCcan has poor burning ability can still serveas an alternative energy sources to wood charcoal for domestic cooking when incorporated with wood charcoal or combine with other biomass. It can be concluded that WACOT RHC if properly treated can be applied in fuel energy production and other composite applications for sustainable waste management in the area.

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I. INTRODUCTION

Biochar is a carbonaceous product (carbon-neutral or even carbon-negative) obtained from the thermochemical conversion of biomass in an oxygen-limited condition (International Biochar Initiative, 2012 and Kumar, *etal,* 2020). Biochardiffers in terms of their physical and chemical characteristics defending often the temperature used for pyrolysis and the feedstock used.

Various studies have been conducted which show that the source of feedstock and heattreatment temperatures are the two major factors that determine thephysiochemical properties of biochar (Waluyo,*etal,* 2023).

Even though charcoal is the most common and best-known type of biochar, all biogenic materials can principally be converted into biochar. The amount of product that can be obtained from the pyrolysis of a given biomass depends on the process conditions, among them temperature and residence time. The attainable mass, energy and fixed carbon yields with their according process conditions are important for the design of an economic biochar production as they indicate the success of the conversion process. Chemical as well as other elemental compositionsof the biocharespecially the amount of carbon content, volatile content and percentage fixed carbon determine the suitability of a given char for biofuel production. Other chemicals compositions of biochar may be suitable for other renewable products generation. Rice Husk as one of the largest waste products obtained from milling process of paddy rice has been used in a variety of applications to produce biofuel and other renewable products after pyrolysis.Pyrolysis is a well-known thermochemical process in which thermal degradation of biomass is performed at an elevated temperature in an oxygen controlled atmosphere (Behazin,*et al*, 2016). Typically pyrolysis can be fast or slow, both of which can affect the physical and chemical properties of biochar. The applications of biochar are very diverse, ranging from heat and power production, flue gas cleaning, metallurgical applications, use in agriculture and animal husbandry, building material, to medical use.The most common application of biocharto day is conversion of the char in to briquette to produce charcoal like product which can serve as alternative and sustainable source fuel energy for domestic cooking and industrial heat generation. The physical and elemental characteristics of biochars produce from fast or slow pyrolysis exhibit changes in the elemental concentration C, H, N, O, S and Ash.

The management and disposal of the rice husk char by rice millers is problematic and many a times associated with serious environmental and human health issues especially due to its low bulk density. WACOT rice husk is significantly pyrolysed at temperature range between 350-500°C, to produce heat energy for power generation and for other production purposes. The resultant char is disposed to the nearby environment as waste product. This research work is designed to determine the physico-chemicals and thermal properties of the RHC for suitability in biofuel production and to significantly reduce waste in the environment.

II. MATERIALS AND METHODS

Sample collection

Rice Husk char used for this study was be collected from the WACOT rice mills industry in Argungudumping site immediately after disposal. The sample was collected weekly for three months August, September and October, making a total of nine samples.50kg will be collected out of which 200g from each sample will be taken for elemental and proximate analysis. The analyzed sample will be label and stored accordingly.

Plate1. Photo captured at disposal site

Physicochemical Analysis

Analysis of chemical and elemental composition C, N, H, O and P, K, Ca, Mg, and Na was determined using elemental analyzer at the department of chemistry, faculty natural sciences Usmanu Danfodiyo university Sokoto, Nigeria.

Briquette Fabrication

Briquette was produced by mixing 75% of char with 15% starch binder and 10% water. The mixed sample was molded in 1.5mm PVC pipe which was later compressed by hitting the sample with a metal hammer for several times. The briquette made was sundried for two weeks before taken to the laboratory for thermal characterization. However three briquette sample were produced with char obtained from three months production cycle (sample **A** for August, Sample **S** September and sample **O** for October production)

Briquette thermal characterization

Test for Ignition

The time taken by briquette to ignite was determined following the method used by Oladeji 2010. The sample was broken in to comparable sizes, ignited at the bottom with aid of waste paper and then allowed to burn until it extinguishes itself. The rate at which fire was propagated was calculated by dividing the distance burnt by the time taken in seconds as shown in equation (2):

Ignition time = $\frac{\text{distance burnt (mm)}}{\text{total time taken (sec)}}$ ……………… (1)

Test for Burning rate

Briquettes burning rate were determined by recording the briquettes weight before burning and after the briquettes were completely burnt, the rate at which fire consume the briquette samples were calculated using equation (3) as reported by Lestari 2012 and Hassan*et al,* 2017

Burning rate$(BR) = \frac{Burnt\ \text{Mass of the Briquette (g)}}{\boldsymbol{Burning}Time\ (mm)}$ ……….. (2)

Water boiling Test

Water Boiling Tests was conducted by combusting 150g of briquettes samples using a fabricated charcoal stove. One liter of water was used for the test. The temperature reading was taken after every minute with mercury in glass thermometer until the water started to boil.Specific fuel consumption duringwater boiling test was calculated using equation (1):

Specific fuel consumption = $\frac{\text{mass of fuel consumed (kg)}}{tatal\ mass\ of\ the\ boiling\ water(litr)}$ ……. (3)

Briquette Durability test

The briquette durability determines briquette handling and transportation quality. Briquettes durability was determined by dropping 1kg of briquette in polythene on a concrete floor for several times. The durability was calculated from the size stability and friability(lost particles). as reported by Waluyo*et al* 2023. The smaller the durability test value means, the less mass is lost. The maximum friability limit (lost particles) is <4%)

The calculation procedure related to the drop test uses the formula:

Size stability % = (100 x s)/S ………………. (4)

Friability % = 100 – Size Stability ………. (5)

S= weight of briquettes before dropping (gram)

s = weight of briquettes after dropping (gram)

Water Resistance Test

The ability of the briquette to absorb and resist water also determines durability, shelf life and handling process. This is determined by immersing 100g of briquette into a beaker of water for 2 minutes. The briquette was removed from water and reweighed; the relative change in weight of the briquette was measured and the percentage of water absorbed was calculated using the equationreported by Adeleke*et al* 2021.

Water absorbed (%) = $\frac{\text{W2}-\text{W1}}{W1}$ x $100. \dots \dots \dots \dots \dots (6)$

Water Resistance (%) = 100 - % water gained. ……(7)

Proximate analyses of fabricated briquette sample

Some proximate properties of briquette determined include percentage moisture content and ash content which directly affect the quality of briquette. Moisture content and ash content were calculated following Wulayo*et al* 2023.

Moisture Content (%) =$\frac{\text{b}-\text{c (gram)}}{b-a(gram)}$ x 10………….. (8)

Where,

a = empty cup weight (gram)

b = cup weight + sample before drying (gram)

c = cup weight + sample after drying (gram)

Ash content was calculated by weighing the remaining content of 100g briquette after being burnt completely to ashes.

III. RESULTS AND DISCUSSION

Ultimate analyses

Table 1 shows the elemental and chemical composition of rice husk char (RHC). The element detected were C and O. The carbon content of any biomass is one of the important elements that determine the suitability for biomass intended for fuel energy production. The percentage C recorded from all the sample was low and ranges between 14.61-16.21, 14.33-12.93 and 10.83- 7.32 for sample A1,A2,A3, S1,S2,S3, and O1,O2 and O3 respectively. Carbon content is an important factor in briquettes as it affects their combustion propertiesthus the low carbon content recorded is an indication that all samples analyzed may be less suitable for renewable fuel energy generation. The low carbon content may be as a result of temperature used and duration of pyrolysis. Fast pyrolysis generate more carbon than slow pyrolysis Behazinet al 2016 and Tomczyk*etal*2020 also indicated that slow pyrolysis may results in low carbon content then fast pyrolysis due more condensation of carbon in the biochar. The Nitrogen N and Hydrogen content not detected in this analysis may be due limited capacity of the elemental analyzer used and the two elements may not matter much to our results. Other chemical detected were P,K,Ca, Mg,Nawhich may be very vital for other application of biochar such soil enhancement, organic and inorganic fertilizer production. Biocharsare abundant in mineral elements such as Na, K, Ca, Fe and Mg (Tomczyket al.2020). Saletnik et al. 2016 reported that the concentrations of these elements also increase with the pyrolysis temperature and vary with the type of feedstock. At higher temperature their concentration can be low

Table1. Chemical composition for WACOT Rice Husk Char

Elements %	RHC Sample per months								
	A1	A2	A3	S1	S2	S3	O1	O2	O3
C	16.21	15.90	14.61	14.33	12.44	12.93	7.32	10.83	8.53
N									
O	47.39	45.41	51.11	43.21	46.44	42.14	49.51	45.22	49.91
H									
Ca	1.33	0.35	1.91	0.35	1.46	0.32	0.31	0.97	1.65
P	0.61	0.34	1.28	0.34	1.56	0.99	2.58	0.26	0.23
K	0.76	0.32	0.30	0.32	0.77	0.47	0.33	0.34	0.33
Mg	1.32	0.36	0.15	0.36	0.70	0.24	0.44	0.22	0.12
Na	0.32	0.45	0.59	0.45	2.16	0.71	1.00	0.73	0.77

Thermal characteristics of RHC Briquettes

Fabrication of Briquette

A

Figure1. Shows the sample of fabricated briquettes produced from WACOT RHC.

B

C

Plate2. **A** (fabricated briquette), **B** (test for ignition) and **C** (Test for burning rate)

Table2 show the thermal or combustion characteristics of biomass briquettes produced from WACOT rice mills carbonized rice husk for three months production cycles.

The result for ignition test indicated that briquettes made from WACOT RHC have higher ignition time for all the three samples. Sample A and S ignited within the range of 1- 1.25min while sample O has low ignition time of 1.91min. The ability to catch fire easily is one of the basic qualities of briquette. It was the average time taken to achieve a steady glowing flame of the fuel material (Hassan,*et al*,2017). The starch binding agent, ratio, the density, porosity and moisture content may be attributed to the faster ignition time of the briquettes samples. (Hassan *et al* 2017) and (Azodeji,*et al*,2022)also observed faster ignitibility of briquettes with low density, less volatile content while,(Unuka,*et al,* 2017) attributed the ignitibility of the briquette to be influence of particle size.

The test for burning rate **table2**indicatesthat all briquettes samples produced burn slowly at the rate of 0.12, 0.089 and 0.069 gram per second for sample A, S and sample O respectively which was comparable with findings of Lestari *et al*, 2015. Burning rate is one of the good thermal characteristics of fuel briquettes. Briquette that burns quickly will not last longer and may produce less heat than the briquette than burns slowly. It was observed that all the briquettes samples burns poorly as none of briquette sample is able burn to ashes completely unless when incorporated with wood. The poor burning ability of the briquette can attributed to low porosity, moisture content and percentage binder.The moisture content of briquettes affects the calorific value and general, the lower the moisture content, the higher the calorific value of the briquettes (Waluyo,*et al*, 2023).Azodeji,*et al* (2022) asserted that briquette with lower fuel burning rate are economical as it required a small amount of time to cook a giving quantity of food.Waluyo*et al*, (2023) also maintain that the longer the briquettes burn to ashes, the better the quality and efficiency of the briquettes. It was observed that, the poor burning ability of these briquettes may be as a result of low carbon content, low volatile content and condition of pyrolysis as the char sample used in the experiment was not pyrolysed for briquette purpose. The addition of other biomass material may improve the burning ability of the briquette.

The test for heating value in and boiling water test **Table2**show the ability of the briquette generate heat per gram and to boil water or cook food at a given time. The average heat generated was 0.66, 0.66 and 0.53 for sample A, S and O respectively. This shows that all briquette samples has low heating value when compared with other reports and that briquettes made from WACOT RHC may be less suitable for solid fuel production unless incorporated with other biomass. Lestari *et al*,(2017)reported an optimum burning temperature of 499.2°C from carbonized saw dust char briquette. The failure of the briquette samples to boil the sample of water used can directly be attributed to low heating value.

The result for durability was measured base on size stability and friability which determine the strength of the briquette to withstand rigorous handling, transportation, storage and weather conditions on occasions where the products will be transported and or exported. The result show that the average percentage size stability of the briquette samples obtained were 97.72, 97.43 and 98.21 while the percentage friability were 2.28, 2.57 and 1.72 for sample A, S and O respectively which is lesser than maximum friability limit (lost particles) of<4% (ASTM-D440-49, 2007 and 20017). The durability index obtained from this experiment is as a result of binding ratio and compressive strenght of the briquette. This findings is closely related to the findings of Imeh*et al*, (2017) who obtained 98.12% durability index of biomass briquette.

The results for Water absorption and water resistance test in **Table2**show the percentage water absorption of 2.02, 2.00 and 1. 72 for sample A,S and O respectively while the percentage water resistance index was 97.98, 98.0 and 98.28 as the former. Briquettes water resistance is crutial factor for storage and transportation in moist conditions. The reslt for water resistance from all the briquette sample was aggeed with quality standards of commercial briquette. Briquette water resistance quality is determine by density and porosity of the material. Law, *et al*, (2017) and Sunday *et,al* (2020) attributed the low water resistance of biomass briquette to be the effect of density and porosty of briquette particles size.

Table2. Thermal characteristics of WACOT Rice Husk Char Briquette

Briquettes characteristics	Sample A	Sample S	Sample O
Ignition time (mm/s)	1.25	1.07	2.14
Burning rate (g/min.)	0.12	0.089	0.069
Heating value (°C/gram)	0.66	0.66	0.53
Water boiling time (Min.)	-	-	-
Moisture content (%)	6.4	10.7	4.9
Ash content (%)	48	48.9	51.0
Size Stability (%)	97.72	97.43	98.21
Friability (%)	2.28	2.57	1.79

Water absorption	2.02	2.00	1.72
Water Resistance	97.98	98	98.28

IV. CONCLUSION

This study demonstrated that briquettes produced from WACOT RHC residues show comparable results in terms of proximate, thermal and ultimate analysis of briquettes. From this study, it could be concluded that WACOT RHC has low carbon content and calorific value among all sample due to uncontrolled carbonization process. The results of the study also show that briquette produced from the WACOT RHC has poor burning rate and low heating value with comparable briquette quality standards of other parameters with commercial briquettes.It can therefore, be concluded that incorporation of WACOT RHC with other biomass may improve its Carbon content, heating value and burning ability. WACOT RHC if properly treated can be converted to briquette and other composite materials for sustainable fuel energy production and sustainable waste management.

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