Characterization of rice husk briquette mixed with cassava starch and clay paste for optimum heat generation

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Abstract: The reuse and recycling of rice husk waste help to reduce huge volumes of rice husk from milling industries and solve environmental challenges. In this study, the best mix ratio of rice husk briquette mixed with cassava starch for optimum heat generation was determined. It also determined the effect of clay paste on the heat generation property of the rice husk briquette. Rice husk briquettes with 0.15 – 0.20 cm s^{-1} flame propagation and density of 0.2041 – 0.2449 g cm^{-3} were used. Two sets of specimen were prepared. Specimen I was the rice husk – cassava starch mixture. It was mixed at the mixing ratios of 90:10, 80:20, 70:30, 60:40, and 50:50. Specimen II, which was rice husk – cassava starch – clay paste mixture, was mixed at the mixing ratios of 90:8:2, 80:16:4, 70:24:6, 60:32:8, and 50:40:10. The response of heat generation to the mix ratio changes and effect of clay paste on heat generation property were determined. The findings of the study indicate that an increase of the proportion of cassava starch in the rice husk briquette increases heat generation but reduces longevity of the rice husk briquette. The optimum heat generation mix ratio was identified to be 80:20, since it takes the minimum time (6 minutes) to reach the boiling point of water without total extinction of the briquette. Clay paste additive increases heat generation and longevity of rice husk briquette. A 20% clay paste replacement of cassava starch reduces the boiling time of the water by 1 minute for the 80:20 mix ratios. Clay paste has potential to be used as an additive in the production of briquettes for increased heat generation and longevity. The findings of the study could find application in the waste reuse and recycling industries.

Keywords: rice husk, cassava starch, clay paste, heat generation

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1 Introduction

Rice is a staple food crop that is grown in a commercial form in many parts of the world. The outer layer of rice grain obtained from the paddy milling process is known as rice husk. (Saeed et al., 2021). Yahaya and Ibrahim (2012) stated that rice husk compared to other agro residues has higher ash content (20%-22.4%), higher potash content, 1.0% crude protein, 0.3% crude fat, and 30% carbohydrate. One of the environmental problems imposed by rice industry is high buildup of rice husk that are burned round the year evolving dangerous gases to the environment that cause diseases to human being. According to (Pode, 2016), rice husk can be used as landfills that may cause storage and operational problem, as well as serious environmental degradations if not managed well. It agrees with study of (Moayedi et al., 2019), that rice husk has some potential especially in the waste reuse and recycling industries.

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Solid waste recycling according to Eze and Edu (2014) anchored on how to manage solid waste in a scientific manner that meet the public health and environmental conditions to reuse and recycle waste materials. The recycling of the waste (rice husk) could help to reduce huge volumes of rice husk from milling industries, which invariably have great potentials that can be used to solve some environmental problems. The use of rice husk in the production of briquette is vital toward reuse and recycling of waste for environmental sustainability, as the society interest increases in the waste-to-wealth technology.

The rising need for energy as a result of population growth has long been a source of concern. High cost of cooking gas, Kerosene and firewood, which most rural dwellers rely on for energy source, is very difficult to handle, store, transport and utilize in their raw form. This has led to insufficient energy consumption, which has reduced optimum production or crippled so many industries in Nigeria. Heat generation challenges for cooking and burning has become a subject of discussion among researchers in seminars, workshops and conferences. It is believed that apart from the high cost of the conventional heat generation methods, they cause so many environmental defects and pollutions. Although numerous studies have been conducted to arrest the challenges, yet environmental pollution is still a source of worry to the public. The accumulation of rice husk at certain sites has caused solid waste problems in different locations in agro-based communities. Though rice husk has found applications in some waste recycling and reuse industries, more usages are yet to be unveiled, especially for the heat generation industry.

The problems motivated researchers to develop briquette technology. Balat and Ayar (2005) supported that briquette production is one of the solutions to the above problems. Briquette is a small block of flammable biomass that can be used for cooking and heating mostly in developing countries. Briquette is a compacted block of combustible biomass material used for fuel and kindling to set a fire (Editors of The American Heritage Dictionaries, 2016). FAO (2014) stated that briquette is a compacting method that increases the low bulk density of biomass to a high density. Rice husk briquette is a biofuel constitute of rice husk and binder to replace coal and charcoal that are mostly used in the developing world in cooking and heating. Saeed et al. (2021) stated that rice husk-based briquette has low bulk density (14%) and low moisture content (10% average) resulting to low durability and high calorific value of 17.688 MJ Kg^{-1}. Briquette was defined by Martha et al. (2017) as a technique for maximizing the use of waste from rice farming and industrial processing. The study analyzed the briquette quality produced from rice husk and husk ash. Compositions were determined without the proportional ratio of the briquette materials. Obi and Okongwu (2016) characterized fuel briquette made from rice husk and palm oil mill sludge. The study determined the physical and combustion properties of the briquette, but palm oil sludge is not easily sourced. Eze et al. (2019) used two different materials, namely; paper and clay as binders but did not properly characterize the composition, which led to cracks on both rice husk clay and rice husk paper briquettes.

Jamradloedluk and Wiriyaumpaiwong (2007) carried out a study on the production of rice husk-based charcoals briquettes. They carbonized, crushed and sieved three different types of biomass, namely bagasse, rice straw, and water hyacinth through screens to obtain the particle size of 150-750 μm. Each sieved specimen was mixed with rice husk charcoal at the ratios of 80:20, 60:40, 40:60, and 20:80 with other charcoal respectively. The mixtures were densified, using cassava starch as binding agent using the cold extrusion process. The findings of the study indicate that the mixing ratio had a significant effect on the physical and mechanical properties of the briquettes. Homdoung et al. (2020) conducted research to evaluate the changes in physico-chemical properties of agricultural corn-cobs and rice husks residues during torrefaction for solid fuel production.

They analyzed the physical properties of the torrefied biomass pellets. The findings revealed that raising the torrefaction temperature and time decreased the moisture and volatile matter content of rice husk and corn cobs. On that note, ash content, fixed carbon, and heating values were all increased at the same time.

Oladeji (2011) investigated properties of briquettes produced from corncob and rice husk residues with a view to finding out which of the two residues examined could be used more efficiently and rationally as fuel. They fabricated a simple prototype briquetting machine to facilitate densification of these residues into briquettes. Their result shows that corncob briquette has more positive attributes of biomass fuel than rice husk briquette. It has 13.47% moisture content, a higher density of 650 kg $m^{-3}$and a lower relaxation ratio of 1.70. Arévalo et al. (2017) proposed a rice husk-based sustainable energy model as well as the production of agricultural waste briquettes. The study obtained briquettes with 4,040 kcal kg^{-1} of heat power and 80.39% combustion efficiency. The study revealed that the utilization of the produced briquette would allow little use of the biofuel compared to firewood and reduce levels of deforestation.

Some researchers like Eze et al. (2021) and Ahiduzzaman (2007) conducted a study on thermal properties which helps in rice processing and the improvement of rice husk energy as well as constraints for technologies dissemination and utilization. The efficiency of rice husk energy technologies was investigated. The benefits of the use of rice husk energy technologies were analyzed and the constraints to its dissemination were found out during the study. The study pointed out that the rice husk briquetting could generate employment and plays a great role to reduce the CO_2.

Although past researchers have carried out studies on briquette production, yet the studies are far from sufficient. The study of the use of materials that could improve the properties of the briquette is yet to be exhausted. The present research seeks to use clay paste and cassava starch as additive and binder to assess their effects on the signature of rice husk-based briquette.

Consequently, the application of binders and other materials in briquette production could improve the properties of rice husk-based briquette. It could enhance heat generation, burning rate, and the briquette longevity and durability. It is based on the above assertion that this research seeks to characterize rice husk briquette mixed with cassava starch and clay paste, and determine the effects on properties of rice-husk-based briquette.

2 Materials and method

This chapter describes the materials and methods used in the study. They are discussed under the following subheadings, namely research area, raw materials, equipment used, preparation procedure and data analysis.

2.1 Research area

The research was conducted in Ebonyi State. It was carried out in the mechanical workshop of Ebonyi State University, Abakaliki, Ebonyi State.

2.2 Raw materials and equipment used for the briquette production

The raw materials used in the study are rice husk, clay paste, and cassava starch. The rice husk was sourced from Abakaliki rice mill, cassava starch was collected from the Iboko Izzi cassava mill, while clay was sourced from Ishieke annex of Ebonyi State University. The materials are presented in Figure 1.

Figure 1 Raw materials

List of Equipment Used :

The equipment used includes the following:

(1) Electronic Weighing Scale (DT 500, 5000 g 01 g): It was used to weigh samples of raw materials

(2)Electric Oven (Galleukam size 2): It was used to dry briquette

(3)Compressing machine: It was used for compression and ejection of briquette

(4)Briquette stove: used for boiling water test

(5) Digital thermometer (CUSTOM TX – 120, -50°C to 250°C): used to measure temperature of the testing water

Other equipment is stopwatch, Bunsen burner, Ejection strokes, sieve, and hydraulic jack.

Figure 2 Equipment used for briquette production

2.3 Preparation procedure

The raw materials were sun dried, sieved and screened to remove impurities that may hinder good results, and ground to powdery form. Two sets of specimen were prepared. Specimen I, was the rice husk – cassava starch mixture. It was mixed at the mixing ratios of 90:10, 80:20, 70:30, 60:40, and 50:50. For Specimen I, rice husk was wet to ensure proper mixing with others. A cooking gas was ignited and water was poured into a pot set on the cooking gas. The water boiled and the hot water was mixed with the cassava starch until a sticky gel was produced. The rice husk was mixed with cassava starch and poured into the mould set on the compression jack.

Specimen II, which was rice husk – cassava starch – clay paste mixture, was mixed at the mixing ratios of 90:8:2, 80:16:4, 70:24:6, 60:32:8, and 50:40:10. The clay powder was added water to form clay paste. Rice husk was wet to ensure proper mixing with others. The wet rice husk was mixed with cassava starch and clay paste, and then poured into the mould set on the compression jack.

In both cases, the mixture inside the mould was pressed with the aid of hydraulic jack and ejection strokes. 1,000 samples of specimen I and 625 samples of specimen II were produced. The samples were ejected out and transferred to oven dryer for removal of moisture content. The dried briquette was graduated in centimeter then ignited over a Bunsen burner. The method of Oladeji (2010) was adopted to estimate the propagation flame by dividing the distance burnt by the time taken in seconds. The burning and physical characteristics of the produced briquette are shown in Tables 1 and 2 respectively.

Table 1 Burning Characteristics of Briquette

Parameter	Unit	Briquette	
		Rice husk and Cassava starch	Rice husk, Cassava starch and Clay paste
Flame propagation	cm s^{-1}	0.20	0.15
Quantity burned	g	800	600
Ash content	%	16	20

Table 2 Physical Characteristics of Briquette

Parameter	Unit	Briquette	
		Rice husk and Cassava starch	Rice husk, Cassava starch and Clay paste
Height	cm	5	5
Diameter	cm	5	5
Mass of briquette	g	20	24
Volume	(cm^3)	98	98
Density	(g cm^{-3})	0.2041	0.2449
Colour	-	Light brown	Brown
Texture	-	Rough	Smooth

2.4 Data mining and analysis

The burning characteristics of each batch of the briquettes were determined. The physical characteristics of each batch of the briquettes were also determined. The time taken to boil two liters of water was as well determined.

3 Results and discussions

This chapter describes and discusses the results of the study. The results are presented and discussed in line with the objectives of the research.

3.1 Determination of best mix ratio of rice husk briquette mixed with cassava starch for optimum heat generation

Figure 3 shows the response of heat generation to the mix ratio changes. For the 90:10 mix ratio of rice husk and cassava, the temperature of the water increased from 25℃ at 0 minute of heating to 85℃ at 6 minutes of heating, and decreased to 84℃ at 7 minutes of heating. The temperature rose to 100℃ at 6 minutes of heating for 80:20 mix ratio.

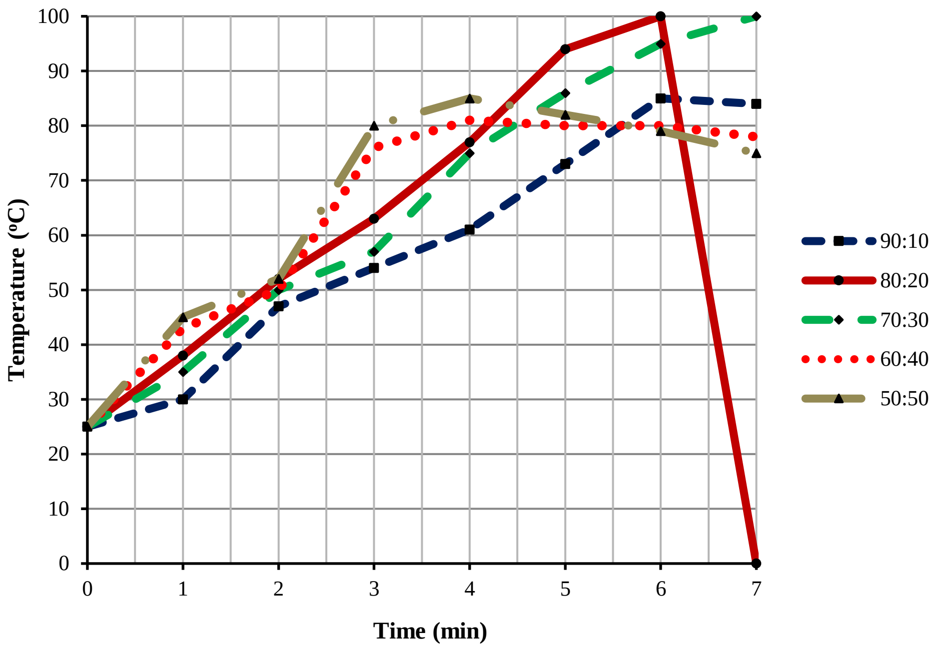

Figure 3 Response of heat generation to the mix ratio changes

Table 3 Water boiling test using rice husk fuel briquette produced with cassava starch as binder

Mixing ratio	10%, 90%		20%, 80%		30%, 70%		40%, 60%		50%, 50%	
	Time (min)	Temp. (℃)	Time (min)	Temp. (℃)	Time (min)	Temp. (℃)	Time (min)	Temp. (℃)	Time (min)	Temp. (℃)
1	0	25	**0**	**25**	0	25	0	25	0	25
2	1	30	**1**	**38**	1	35	1	43	1	45
3	2	47	**2**	**52**	2	50	2	50	2	52
4	3	54	**3**	**63**	3	57	3	76	3	80
5	4	61	**4**	**77**	4	75	4	81	4	85
7	5	73	**5**	**94**	5	86	5	80	5	82
8	6	85	**6**	**100**	6	95	6	80	6	79
9	7	84	**7**	-	7	100	7	78	7	75

For the 70:30 mix ratio, the temperature of the water rose from 25℃ at 0 minute of heating to 100° at 7 minutes of heating. The temperature increased from 25℃ at 0 minute of heating to 81℃ at 4 minutes of heating, and decreased to 78℃ at 7 minutes of heating for 60:40 mix ratio. It rose from 25℃ at 0 minute of heating to 85℃ at 4 minutes of heating, and decreased to 75℃ at 7 minutes of heating for 50:50 mix ratios. The results indicate that an increase of the proportion of cassava starch increases heat generation but reduces longevity of the rice husk briquette. The discovery is in line with the submission of Jamradloedluk and Wiriyaumpaiwong (2007) that mixing ratio has an effect on the physical and mechanical properties of the briquettes. The findings of the study show that the optimum heat generation mix ratio is 80:20, since it takes the minimum time (6 minutes) to reach the boiling point of water without total extinction of the briquette.

3.2 Effect of clay paste on heat generation property

Figure 4 shows the effect of clay paste on the heat generation property of rice husk briquette mixed with cassava starch as a binder. A 25% clay paste replacement of cassava starch in the 90:10 mix ratio produces a 3℃ temperature increase at 6 minutes of heating. The 25% clay paste replacement of cassava starch reduces the boiling time of the water by 1℃ for 80:20 and 70:30 mix ratios. It caused a 2 ℃ temperature increase at 7 minutes of heating for 60:40 mix ratio. The findings of the study show that clay paste as an additive increases heat generation and longevity of rice husk briquette. It supports the assertion of Eze et al. (2019) that additives affect properties of briquettes.

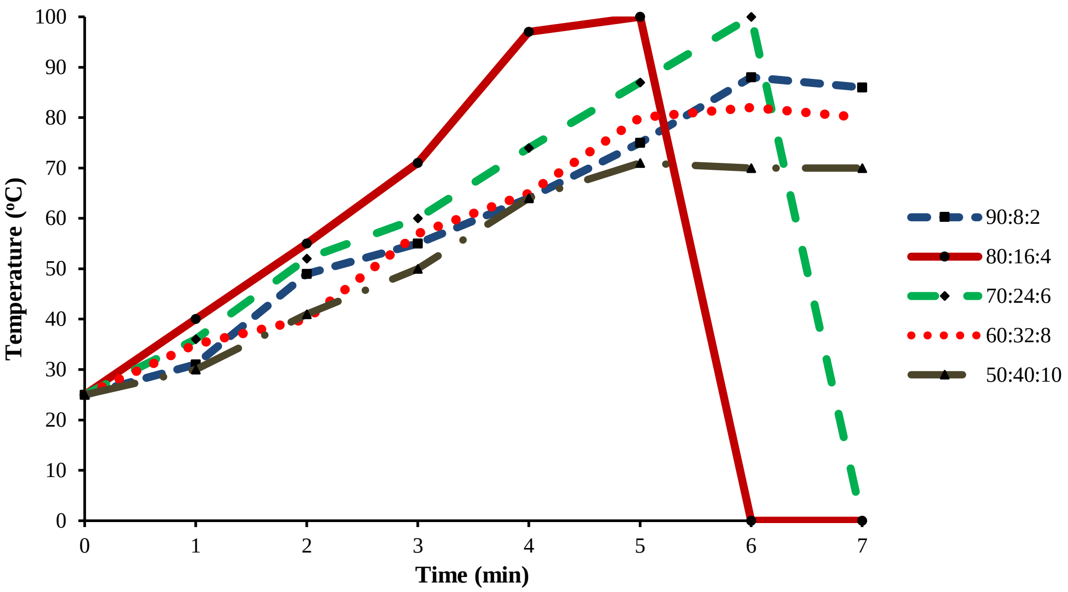

Figure 4 Effect of clay paste on heat generation property

Table 4 Water boiling test using rice husk fuel briquette produced with clay paste and cassava starch as binder for optimization

Mixing ratio	2%, 8%, 90%		4%,16%, 80%		6%, 24%, 70%		8%,32%, 60%		10%,40%,50%	
	Time (min)	Temp. (℃)	Time (min)	Temp. (℃)	Time (min)	Temp. (℃)	Time (min)	Temp. (℃)	Time (min)	Temp. (℃)
1	0	25	**0**	**25**	0	25	0	25	0	25
2	1	31	**1**	**40**	1	36	1	35	1	30
3	2	49	**2**	**55**	2	52	2	40	2	41
4	3	55	**3**	**71**	3	60	3	57	3	50
5	4	64	**4**	**97**	4	74	4	65	4	64
7	5	75	**5**	**100**	5	87	5	80	5	71
8	6	88	**6**	**-**	6	100	6	82	6	70
9	7	86	**7**	**-**	7	-	7	80	7	70

4 Conclusions

Rice husk has been identified as a waste material for the production of briquette. In this research, rice husk briquettes with 0.15 – 0.20 cm s^{-1} flame propagation and density of 0.2041 – 0.2449 g cm^{-3} were used. The findings of the study indicate that an increase of the proportion of cassava starch in the rice husk briquette increases heat generation but reduces longevity of the rice husk briquette. The optimum heat generation mix ratio was identified to be 80:20, since it takes the minimum time (6 minutes) to reach the boiling point of water without total extinction of the briquette. Clay paste additive increases heat generation and longevity of rice husk briquette. A 20% clay paste replacement of cassava starch reduces the boiling time of the water by 1minute for 80:20 mix ratios. Clay paste has potential to be used as an additive in the production of briquettes for increased heat generation and longevity. However, further research needs to be conduction in this area to enhance efficient home and industrial briquette production.

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