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VALORIZATION OF AFRICAN OIL BEAN SEED HUSK TO DEVELOP SOLID BIOFUEL FOR GREEN SUSTAINABILITY AND CIRCULAR BIOECONOMY

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Abstract
Fossil fuel, which dominates the world's energy supply, faces serious environmental and sustainability challenges. This study investigated the production and evaluation of bio-briquettes from African oil bean seed husk (AOBSH) and sawdust (SD), bound with cassava starch, to offer a sustainable and eco-friendly alternative to fossil fuel. A multi-level factorial experimental design was employed, involving five biomass (AOBSH and SD) blend ratios and three binder quantities (30 g, 50 g, and 80 g). The physical and energy-related properties of both uncharred and carbonized briquettes, including moisture content, ash content, volatile matter, fixed carbon, and calorific value were studied. For uncharred briquettes, fixed carbon ranged from 0.24% to 15.83%, volatile matter from 19.05% to 45.74%, ash content from 5.4% to 36.23%, and moisture content from 33.5% to 51%. Carbonized briquettes exhibited improved characteristics, with fixed carbon reaching up to 53.65% with significantly reduced volatile matter. Results also indicated that biomass composition significantly influenced fixed carbon, volatile matter, and moisture content, while binder quantity had a lesser effect. Interaction plots confirmed that optimal briquette quality was driven more by biomass composition than binder quantity. The best briquette was obtained from carbonized AOBSH at 100 % composition with 80 g of cassava starch binder, and this briquette gave a fixed carbon content of 53.65 % and a calorific value of 54.00 kJ/kg. The study concludes that briquettes made from AOBSH and SD using cassava starch binder has great potential for clean energy generation and agricultural waste valorization. This innovation promotes sustainable energy goals and rural energy diversification strategies.

Keywords: Biomass, African oil bean seed husk, Sawdust, Cassava starch, Briquette, Calorific value

1. INTRODUCTION

Global energy demand continues to rise sharply, driven by rapid population growth, urbanization, and industrial expansion. Fossil fuels, including coal, oil, and natural gas, have powered economies for more than 150 years and still supply about 80 % of the world's energy. Since fossil fuels are finite and their combustion releases greenhouse gases and pollutants, there is an urgent need to transition to cleaner, renewable, and more sustainable energy sources (Environmental and Energy Study Institute, 2023). Many households in the rural and semi-urban areas of developing nations are confronted with energy challenges because of unavailability and insufficient energy generation and distribution (Oseni, 2012; Pelz *et al.*, 2023; Olubusoye *et al.*, 2026). This slows down economic activities and promotes the use of forestry resources like charcoal and firewood as energy sources. Though forestry resources hold a significant place in driving energy sustainability globally, it should be properly harnessed. The use of charcoal and firewood contributes significantly to environmental pollution, degradation and deforestation (Yirijor and Bere, 2024).

On the other hand, agricultural activities leave behind massive waste which contributes substantially to greenhouse gases (GHGs) emissions upon decomposition (Lee *et al.*, 2022; Patel and Panwar, 2023). Agriculture is being promoted as a sure way to boost the economy of many nations, and an increase in agricultural production comes with an increase in biomass. Biomass is one of the most promising renewable energy sources due to its abundance, carbon neutrality, and versatility. Briquetting, compressing loose biomass into dense blocks, converts low-density residues into a high-density fuel. It is among the technologies used to harness the energy available in biomass (Song *et al.*, 2020). Compared with firewood and charcoal, briquettes have a higher energy concentration and burn for longer because they are denser, drier (NguyenStarch, 2023), and produce less smoke (Yirijor and Bere, 2024), making them cleaner and efficient fuel. The compact shape and size allow briquettes to be stacked and transported easily.

Many agricultural wastes have potential for upscaling as alternative and renewable energy sources through briquetting. Briquetting as a green sustainable energy has the advantages of discouraging deforestation, waste reuse, promoting carbon neutrality, reducing greenhouse gas emission, and serve as a better alternative to fossils fuels. As a result, various agricultural wastes have been investigated for their effectiveness as briquettes. Among the crops' residues studied were breadfruit pulp (Ezenwa, Mgbemena and Emagbetere, 2024), vineyard waste (Senila *et al.*, 2022), ramie (*Boehmeria nivea*), sacha inchi (*Plukenetia volubilis*), and palm kernel shell (*Elaeis guineensis*) (Wulandari *et al.,* 2024), coconut shell (Yirijor and Bere, 2024), rice husk, maize cobs, palm kernel shell, and sawdust (Sunnu *et al.*, 2021), maize cob (Sunardi *et al.*, 2019). Briquetting agricultural waste adds value to agricultural byproducts, promotes circular economy through material recovery and waste elimination, resource efficiency and environmental sustainability.

The African oil bean (*Pentaclethra macrophylla* Benth.), native to West and Central Africa, is an orphaned crop because of dearth of research on the crop (Igbozulike *et al.*, 2021). Research efforts on African oil bean seed (*Pentaclethra macrophylla*) over the years have concentrated on its nutritional composition, fermentation characteristics, physicochemical properties, microbial quality, drying and processing potentials while neglecting the possible utilization of its husk as a valuable by-product (Ejiofor *et al.*, 1987; Njoku and Okemadu, 1989; Okafor *et al.*, 1991; Enujiugha, 2003; Asoegwu *et al.,* 2006; Ikhuoria *et al.*, 2008; Alinnor and Oze, 2011; Nwokeleme and Ugwuanyi, 2015; Ohiri and Bassey, 2017; Okorie *et al.*, 2017; Igbozulike *et al.,* 2023; Obianom *et al.*, 2024). Large quantities of African oil bean seed husks (AOBSH) are generated as waste during processing and are often discarded (Madukasi *et al.*, 2016). Briquetting AOBSH provides an alternative energy source that offers many advantages over fossil fuels like coal and charcoal. AOBSH is used as firewood in Nigeria, and it has the advantage of producing little or no smoke and having great heating ability. So, the solid fuel produced from densification of AOBSH has the potential of being smokeless with high calorific value. Furthermore, sawdust, a byproduct of wood processing industries, also offers significant potential for waste valorization. It is one of the most abundant biomass residues, particularly in forest-rich regions like Nigeria, where improper disposal causes environmental pollution. Densification and torrefaction of sawdust improve its physico-mechanical properties and produce briquettes suitable for heating applications (Waheed *et al.*, 2023). Besides, briquetting typically requires a binder to ensure cohesion and durability of the compacted biomass. Organic binders are preferred over inorganic binders because they contribute less ash. Among organic binders, cassava starch has been reported to have a comparatively high lower heating value (LHV) (19.08 MJ kg^{-1}) and therefore increases the energy content and durability of briquettes (Ezéchiel *et al.*, 2022).

Several studies have explored biomass briquette production using husks, shells, bagasse, leaves, peels, stalks, straw, and stems of various crops' residues (Oni *et al.,* 2020, Udoma and Ndirika, 2020; Nagarajan and Prakash, 2021; Bot *et al.*, 2022; Ganesan and Vedagiri, 2022; Ojunjobi *et al.*, 2022; Sabo *et al.*, 2022; Velusamy *et al.*, 2022; Bot *et al.*, 2023; Bot *et al.*, 2024; Wang *et al.,* 2024; Abineno *et al.*, 2025; Ugwu *et al.*, 2026). None of these researchers and others in literature, to the best of our knowledge, have beamed research light on AOBSH alone or in combination with sawdust to produce briquette. So, the potential of AOBSH to yield high-performance briquettes remains uninvestigated, especially regarding the influence of binder concentration and biomass ratios on fuel properties such as calorific value, bulk density, and mechanical strength. Moreover, the sustainable utilization of this crop residue aligns with global goals for green sustainability, circular bioeconomic, environmental protection, and renewable energy access. Valorization of AOBSH through briquetting is an efficient way of adding value to the product, increasing farmers' income and promoting circular economy for sustainable and responsible consumption. The objective of this study, therefore, is to develop and characterize solid fuel briquettes produced using AOBSH alone and in combination of sawdust at varying ratios with cassava starch as organic binder.

2. MATERIALS AND METHODS

This study employed a multi-level categorical experimental design to evaluate the effects of biomass composition and binder quantity on the physical and energy properties of briquettes produced from AOBSH and sawdust, using cassava starch as a binder. The experimental setup facilitated the simultaneous investigation of two key factors, biomass composition and binder quantity, each at multiple levels, enabling comprehensive analysis through randomized trial runs.

2.1 MATERIALS

2.1.1 ***Biomass Materials***

Biomass materials consisted of African oil bean seed husk (AOB) and sawdust (SD), while cassava starch was used as the binder. AOBSH was sourced from a local agricultural processing center located at Enyiogugu market in Ngor Okpala Local Government Area of Imo State. Sawdust was sourced from timber markets in Ahiaeke, Umuahia, Abia State. All biomass samples were stored under controlled conditions to minimize contamination and moisture absorption.

2.1.2 Instruments

The instruments used for the experiment include a weighing balance, vernier caliper, cylindrical mold, crusher, metal trays, laboratory oven, furnace, thermometer, hand press, mixing bowls, calorimeter, hammer, saw, meter rule, fire extinguisher, and an HP Windows 10 laptop with Design Expert Version 13 software.

2.2 Methods

2.2.1 Binder preparation

The cassava starch binder was extracted from cassava harvested at the National Root Crops Research Institute (NRCRI), Umudike. The starch was obtained through a process involving grating, pressing, settling, and drying the cassava pulp. It was then prepared as a thick paste by dissolving the dry starch in water to achieve the required adhesive consistency.

2.2.2 Briquette formulation

Briquettes were formed by crushing the AOBSH using a hammer mill and mixing it with sawdust in various ratios: 100 % AOBSH, 75 % AOBSH and 25 % SD, 50 % AOBSH and 50 % SD, 25 % AOBSH and 75 % SD, and 100 % SD. For each composition, cassava starch binder was added at three levels 30 g, 50 g, and 80 g. The biomass mixtures were weighed and manually blended with the starch solution before being compacted into cylindrical shaped briquettes using a hand press under increasing pressure. Each formulation was evaluated for physical and combustion properties.

2.2.3 Carbonization of briquettes

The freshly pressed briquettes were air-dried to reduce moisture content and then carbonized in a muffle furnace under limited oxygen.

2.2.4 Determination of briquettes properties

To assess the briquettes' quality, standard tests were conducted to determine moisture content, ash content, volatile matter, fixed carbon, and calorific value. Moisture content was measured by oven-drying samples at 105 °C for 60 minutes and calculated as the percentage weight loss from wet to dry sample using ASTM D2216. Ash content was determined following ASTM D-3174 by incinerating the briquettes and measuring the incombustible residue. Volatile matter was quantified based on ASTM D-3175 (2018) by heating samples in a furnace at 900 °C for 7 minutes. Fixed carbon was computed by subtracting the measured moisture, ash, and volatile matter percentages from 100 %. The calorific value, representing the energy content of each briquette, was estimated using the sum of fixed carbon and volatile matter percentages, following the equation provided by Adetogun *et al.* (2014).

2.2.5 Analysis of data

Statistical analysis of the experimentally obtained data was carried out using Design-Expert software version 13. Analysis of variance (ANOVA) was employed to determine the statistical significance of the model and experimental factors, while regression coefficients, coefficient of determination (R^2), adjusted R^2, predicted R^2, and lack-of-fit tests were used to evaluate model adequacy.

3. Results and Discussion

The briquettes – carbonized and uncharred - produced from the experiment are shown Figure 1.

Figure 1: Some carbonized and uncharred biomass briquettes produced.

3.1 Effects and Interactions for Uncharred African Oil Bean and Sawdust Composition Briquettes Developed with Cassava Starch Binder

The experimental result (Table 1) shows the measured responses of briquettes made from varying proportions of AOBSH and sawdust (SD), combined with different quantities of cassava starch binder. Fixed carbon content ranged from 0.24 % to 15.83 %, with the lowest value observed in SD 100 % at 80 g binder and the highest in AOBSH 100 % at 50 g binder. This wide variation (ratio = 65.96) suggests that biomass composition has a dominant effect on fixed carbon. Volatile matter varied from 19.05 % to 45.74 %, ash content from 5.4 % to 36.23 %, and moisture content from 33.5 % to 51.0 %. These values imply that the developed briquettes fall within acceptable limits for thermal applications. High volatile matter and low moisture content (as seen in AOBSH 25 % and SD 75 % at 33.5 % moisture) favour easier ignition and efficient combustion.

Table 1. Multi-level categorical experimental design of observed factors and derived responses for briquette

std	Run	Uncharred Biomass composition	Binder quantity (g)	Fixed carbon %	Moisture content %	Ash content %	Calorific value kJ/kg	Volatile matter %
10	1	SD 100%	50	4.11	46.8	6.61	46.59	42.48
11	2	AOBSH 100%	80	9.69	34.3	16.91	48.79	39.1
9	3	AOBSH 25% & SD 75%	50	2.48	33.5	16.22	40.28	37.8
2	4	AOBSH 75% & SD 25%	30	9.56	50	11.39	38.61	29.05
5	5	SD 100%	30	0.63	45.4	17.39	37.21	36.58
4	6	AOBSH 25% & SD 75%	30	5.85	51	9.68	39.32	33.47
7	7	AOBSH 75% & SD 25%	50	15.4	37.8	9.35	52.85	37.45
13	8	AOBSH 50% & SD 50%	80	4.75	41.4	12.59	46.01	41.26
8	9	AOBSH 50% & SD 50%	50	9.64	45.04	9.8	45.16	35.52
14	10	AOBSH 25% & SD 75%	80	3.52	44.9	11.97	43.13	39.61

1	11	AOBSH 100%	30	2.62	42.1	36.23	21.67	19.05
6	12	AOBSH 100%	50	15.83	35.4	8.62	55.98	40.15
15	13	SD 100%	80	0.24	41.8	14.57	45.98	45.74
3	14	AOBSH 50% & SD 50%	30	9.22	50	6.52	43.48	34.26
12	15	AOBSH 75% & SD 25%	80	14.18	41.1	5.4	53.5	39.32

From the Analysis of Variance (ANOVA), it was observed that fixed carbon and volatile matter responses were statistically significant ($p < 0.05$), with F-values of 4.03 and 4.49, respectively (Table 2). This suggests that these models can adequately predict physical behavior. Moisture content was marginally non-significant ($p = 0.0697$), while ash content was not significant ($p = 0.4284$). Composition (Factor A) had a more substantial effect than binder amount (Factor B) in most cases, reaffirming that the biomass ratio drives briquette quality.

Table 2. ANOVA results for physical property responses for developed briquettes

Source	**Sum of Squares**	**Df**	**Mean Square**	**F-value**	**p-value**	
Response 1: Fixed carbon						
Model	283.98	6	47.33	4.03	0.0369	significant
A-Uncharred Biomass Composition	241.91	4	60.48	5.15	0.0238	
B-Binder Quantity	42.07	2	21.03	1.79	0.2279	
Residual	94.03	8	11.75			
Cor Total	378.01	14				
Response 2: Moisture content						
Model	313.89	6	52.31	3.13	0.0697	not significant
A-Uncharred Biomass Composition	124.13	4	31.03	1.85	0.2121	
B-Binder Quantity	189.76	2	94.88	5.67	0.0293	
Residual	133.92	8	16.74			
Cor Total	447.81	14				
Response 3: Ash content						
Model	358.37	6	59.73	1.12	0.4284	not significant
A-Uncharred Biomass Composition	262.02	4	65.5	1.23	0.3715	
B-Binder Quantity	96.36	2	48.18	0.9034	0.4428	
Residual	426.62	8	53.33			
Cor Total	785	14				
Response 5: Volatile matter						
Model	430.66	6	71.78	4.49	0.0275	significant
A-Uncharred Biomass Composition	125.04	4	31.26	1.96	0.1946	
B-Binder Quantity	305.62	2	152.81	9.56	0.0076	
Residual	127.86	8	15.98			
Cor Total	558.52	14				

Table 3 presents fit statistics for each model. Fixed carbon and volatile matter models had relatively strong R² values (0.75 and 0.77), with moderate adjusted R² values. However, predicted R² was lower, indicating potential model improvement needs. Adequate precision exceeded 4 for all parameters except ash content, meaning the models (except for ash) are suitable for navigating the design space.

Table 3. Fit statistics results for physical property responses for developed briquettes

	Fixed carbon	**Moisture content**	**Ash content**	**Volatile matter**
Std. Dev.	3.43	4.09	7.3	4
Mean	7.18	42.7	12.88	36.72
C.V. %	47.74	9.58	56.68	10.89
R²	0.7512	0.7009	0.4565	0.7711
Adjusted R²	0.5647	0.4767	0.0489	0.5994
Predicted R²	0.1255	-0.0514	-0.9106	0.1952
Adequate Precision	6.5339	5.798	3.6073	7.0879

On the other hand, the relationship among the experimental variables is shown using the interaction plots for fixed carbon, moisture, ash content, and volatile matter (Figure 2).

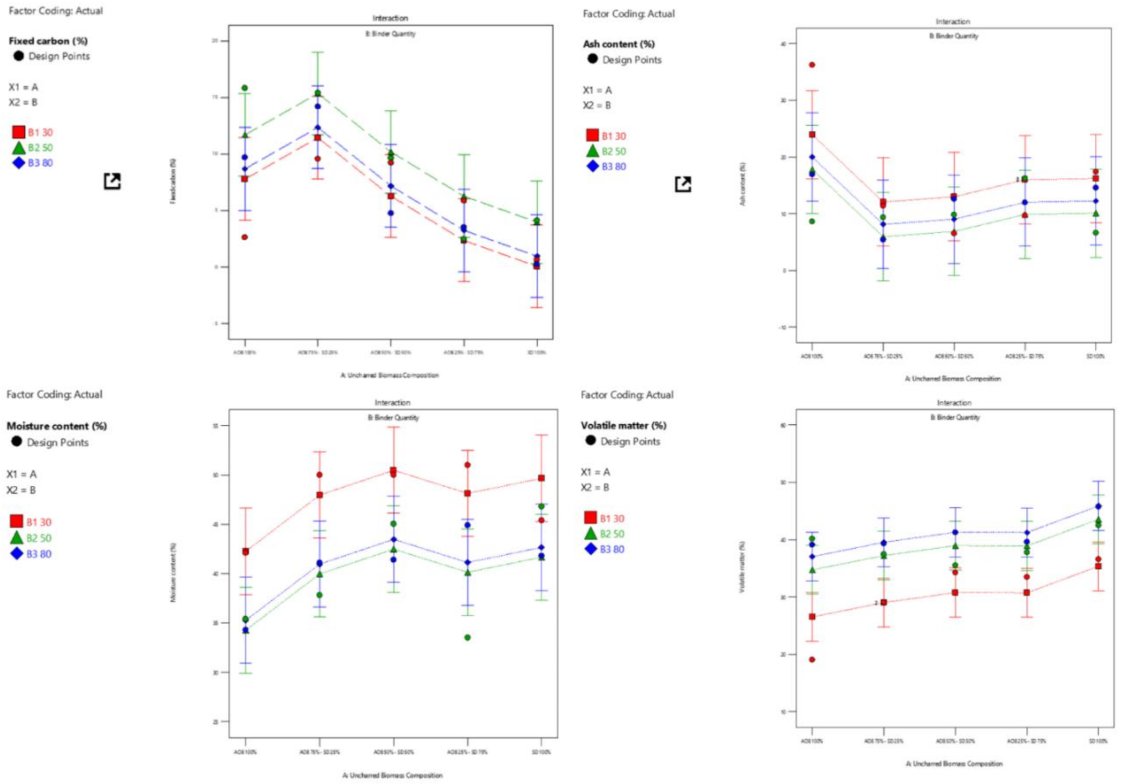

Fig 2: Interaction plot effects of the fixed carbon, moisture, ash content, and volatile matter on uncharred biomass composition

For fixed carbon, a peak was observed at 50 g binder for AOB-rich compositions. SD 100% yielded the lowest fixed carbon regardless of binder amount (Figure 2a). Figure 2b showed decreased value with binder from 30 g to 50 g but varied at 80 g. AOB 75% - SD 25% showed the highest moisture. The interaction of the ash content with the biomass in Figure 2c indicated increased with binder quantity, especially in SD 100% and AOB 50%-SD 50%. AOB 75%-SD 25% had lower ash levels. Figure 2d depicted increased consistently with binder level, except for AOB 100% which showed a slight decline at 80 g.

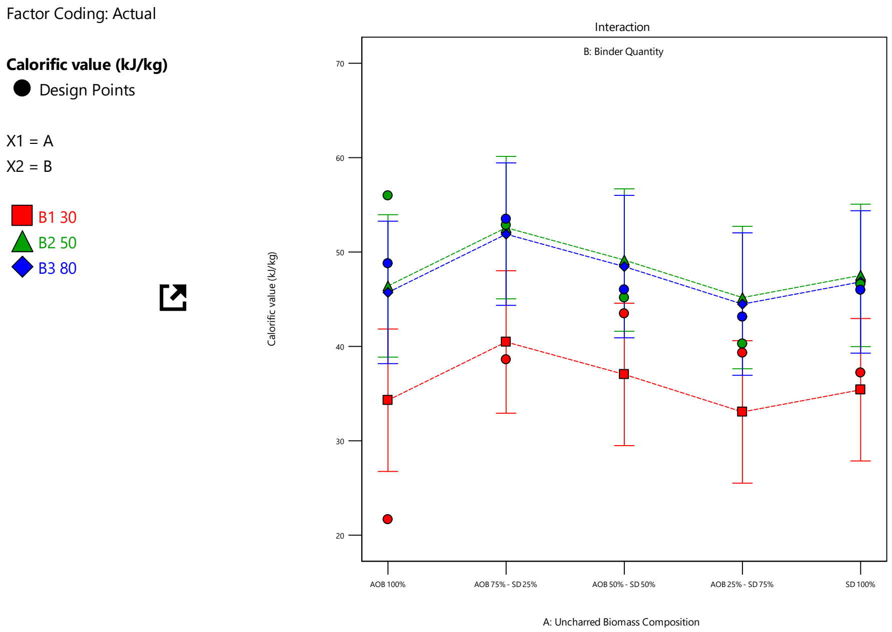

Fig. 3a: Calorific values interaction plot

The calorific values improved by increasing binder up to 50 g across all compositions, as shown in Figure 3a. Beyond this, the value plateaued or declined slightly. AOB 75%-SD 25% produced the highest energy values. Figure 3b (3D surface) confirms the optimal balance of biomass ratio and moderate binder quantity.

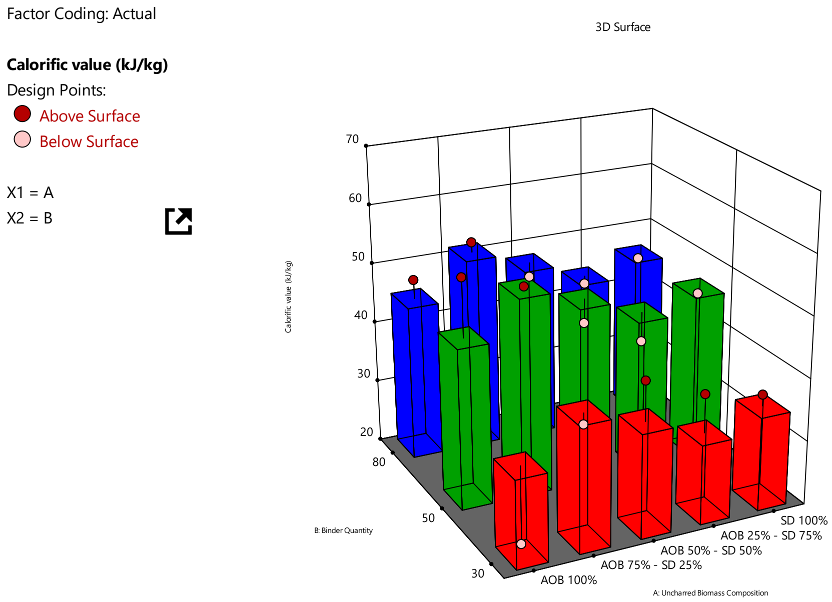

Fig. 3b: 3D surface diagram representation on interactions of biomass composition and binder amount on the calorific values.

3.2 Effects and Interactions for Carbonized African Oil Bean and Sawdust Composition Briquettes

The experimental result revealed that the values of fixed carbon increased significantly, ranging from 7.12 % to 53.65 % (Table 4). Moisture content varied between 28.46 % and 57.67 %, ash content between 6.9 % and 44 %, and volatile matter remained low (0.26 % to 0.37 %).

Table 4: Multi-level categorical experimental design of observed factors and derived responses for carbonized briquettes

std	Run	Carbonized Biomass composition	Binder quantity (g)	Fixed carbon %	Moisture content %	Ash content %	Calorific value kJ/kg	Volatile matter %
3	1	AOB 50% - SD 50%	30	47.36	45.4	6.9	47.7	0.34
5	2	SD 100%	30	32.19	57.67	9.86	32.47	0.28
13	3	AOB 50% - SD 50%	80	37.34	44.29	18.02	37.69	0.35
15	4	SD 100%	80	37.37	50	12.27	37.74	0.37
10	5	SD 100%	50	7.12	48.62	44	7.38	0.26
9	6	AOB 25% - SD 75%	50	35.95	50.25	13.48	36.27	0.32
14	7	AOB 25% - SD 75%	80	29.92	43.39	26.36	30.25	0.33
8	8	AOB 50% - SD 50%	50	35.31	52.33	12.05	35.62	0.31
7	9	AOB 75% - SD 25%	50	45.7	41.2	12.75	46.05	0.35
1	10	AOB 100%	30	50.49	31.03	18.18	50.79	0.3
11	11	AOB 100%	80	53.65	35.79	10.21	54	0.35
12	12	AOB 75% - SD 25%	80	41.25	42.51	15.89	41.6	0.35
4	13	AOB 25% - SD 75%	30	41.56	48.95	9.23	41.82	0.26

6	14	AOB 100%	50	50.09	28.46	21.18	50.36	0.27
2	15	AOB 75% - SD 25%	30	47.43	38.16	14.12	47.72	0.29

The Analysis of Variance (ANOVA) results in Table 5 showed that only moisture content was statistically significant (p = 0.0079), with biomass composition (Factor A) being the dominant variable. Fixed carbon and volatile matter showed marginal and non-significant effects respectively. Ash content model was not significant

Table 5: ANOVA results for physical property responses for developed carbonized briquettes

Source	**Sum of Squares**	**Df**	**Mean Square**	**F-value**	**p-value**	
Response 1: Fixed carbon						
Model	1336.56	6	222.76	3.56	0.0506	not significant
A-Carbonized Biomass Composition	1134.18	4	283.54	4.54	0.0331	
B-Binder Quantity	202.39	2	101.19	1.62	0.2568	
Residual	500.03	8	62.50			
Cor Total	1836.60	14				
Response 2: Moisture content						
Model	754.34	6	125.72	6.88	0.0079	significant
A-Carbonized Biomass Composition	750.92	4	187.73	10.27	0.0031	
B-Binder Quantity	3.42	2	1.71	0.0935	0.9117	
Residual	146.27	8	18.28			
Cor Total	900.61	14				
Response 3: Ash content						
Model	363.63	6	60.60	0.5972	0.7268	not significant
A-Carbonized Biomass Composition	159.13	4	39.78	0.3920	0.8091	
B-Binder Quantity	204.50	2	102.25	1.01	0.4071	
Residual	811.86	8	101.48			
Cor Total	1175.49	14				
Response 5: Volatile matter						
Model	0.0119	6	0.0020	2.23	0.1451	not significant
A-Carbonized Biomass Composition	0.0027	4	0.0007	0.7632	0.5777	
B-Binder Quantity	0.0092	2	0.0046	5.17	0.0362	
Residual	0.0071	8	0.0009			

Cor Total	0.0190	14

The fit statistics (Table 6) indicate that moisture content had the best model strength ($R^2 = 0.8376$, Adeq Precision = 7.32). The fixed carbon model had a moderate R^2 (0.72), while the ash and volatile matter models were weak. Only moisture and fixed carbon models can reliably guide formulation optimization

Table 6: Fit statistics results for physical property responses for developed carbonized briquettes

	Fixed carbon	**Moisture content**	**Ash content**	**Volatile matter**
Std. Dev.	7.91	4.28	10.07	0.0298
Mean	39.52	43.87	16.30	0.3153
C.V. %	20.01	9.75	61.80	9.44
R^2	0.7277	0.8376	0.3093	0.6261
Adjusted R^2	0.5235	0.7158	-0.2087	0.3457
Predicted R^2	0.0428	0.4290	-1.4281	-0.3143
Adeq Precision	6.4476	7.3202	2.7252	4.2278

Similarly, the interaction of the fixed carbon, moisture, ash content and volatile matter with the carbonized biomass composition is shown in Figure 5. In figure 5a, the fixed carbon decreased slightly at 80 g binder, especially for AOB 25%-SD 75%. The trends of moisture content in figure 5b were close across material compositions and binder levels, confirming the significance observed in ANOVA. In figure 5c, the ash content increased with binder in most mixes except AOB 100% and SD 100%. The volatile matter in figure 5d were relatively stable; SD 100% showed the highest values.

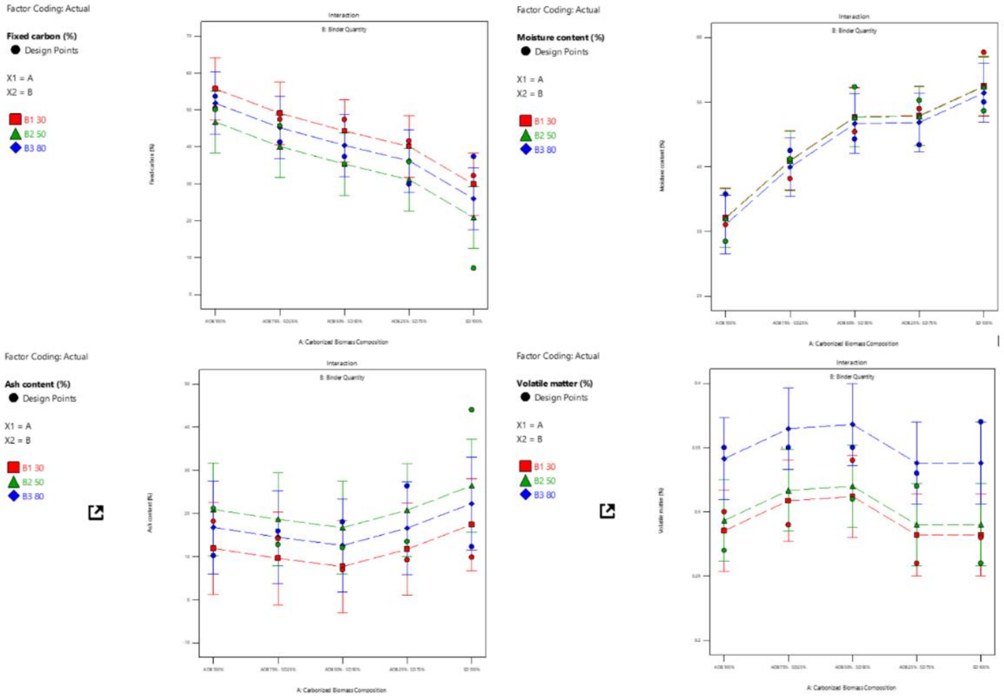

Fig. 4: Interaction plots effects of the fixed carbon, moisture, ash content, and volatile matter on carbonized biomass composition

Contrary to uncharred results, calorific value decreased slightly with binder increase (Figure 5). Carbonized AOB 100% had the highest values at lower binder levels. This suggests that excessive starch may inhibit energy density due to dilution or incomplete combustion.

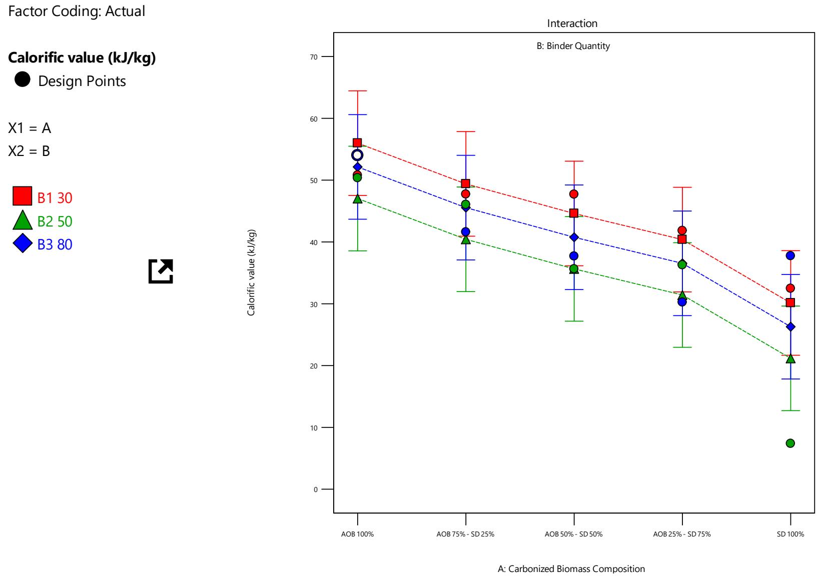

Fig. 5 Calorific values Interaction plot for carbonized briquettes

The interactive influence of biomass composition and binder amount on the calorific values of the carbonized briquettes are shown in Figure 6. It is observed that the addition of binder increased the calorific values up to an optimum level, after which there was a decline in calorific values with increased binder amount.

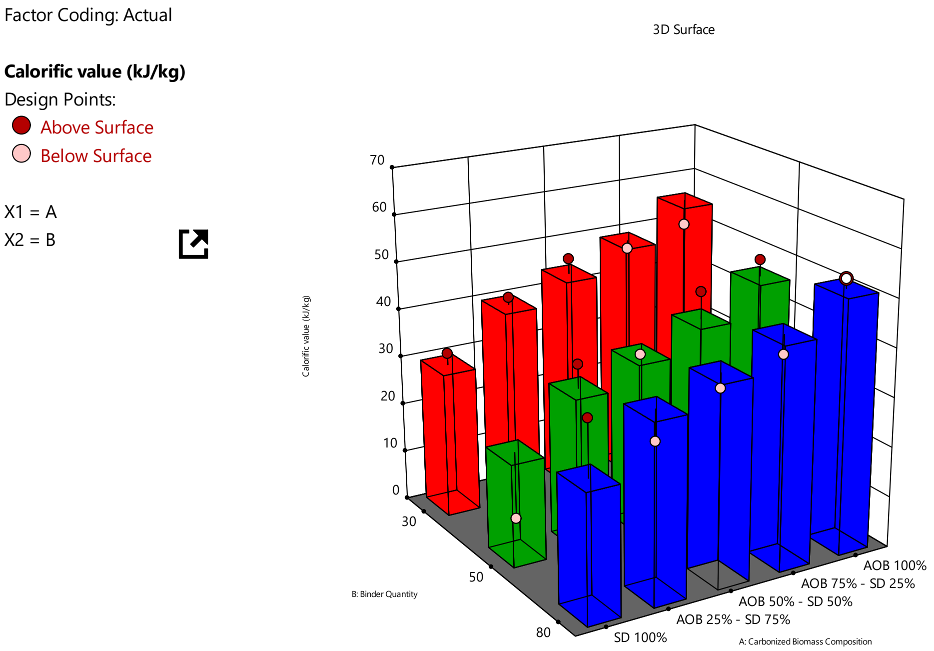

Fig. 6: 3D surface plot on interactions of biomass composition and binder amount on the calorific values for carbonized briquettes.

From the graph, the red region indicates the combinations that gave the highest calorific values. It means that a balanced ratio of biomass to binder enhances briquettes' carbonization efficiency and energy output. Conversely, the less efficient combinations are shown in the blue regions which could possibly be because of excessive binder amount or weak bonding of the carbonized AOBSH and cassava starch. On the other hand, the green region shows moderate performance. In essence, this proves that both the biomass composition and binder quantity are critical and interdependent in determining the efficiency of carbonized AOBSH briquetted. So, optimization of these briquette variables will result in improved solid fuel efficiency.

4. CONCLUSION

This study successfully demonstrated the production and characterization of fuel briquettes using African oil bean seed husk and sawdust in varying proportions, with cassava starch serving as a natural binder. The multi-level factorial design employed in the experimental setup enabled a robust evaluation of the effects of biomass composition and binder quantity on the physical and energy-related properties of the briquettes. Fixed carbon and calorific value were significantly influenced by biomass composition, with briquettes containing higher proportions of African oil bean seed coat generally exhibiting higher fixed carbon content and energy potential. Volatile matter and moisture content showed sensitivity to binder quantity, particularly at 50 g, which optimized combustion-related properties. For carbonized biomass, substantial improvements were observed in fixed carbon and calorific values, confirming the effectiveness of pyrolysis in enhancing fuel quality. Binder quantities beyond 50 g did not significantly improve physical properties and, in some cases, led to a decline in performance metrics.Interaction plots and ANOVA confirmed that biomass composition was the dominant factor influencing briquette quality across all measured parameters. The study affirms the feasibility of utilizing agro-residues such as African oil bean seed husk and sawdust, in combination with a locally available, biodegradable binder, to produce efficient and sustainable fuel briquettes. These findings support the potential for rural energy diversification, green sustainability and valorization of agricultural waste through briquetting technology.

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