INTERNATIONAL JOURNAL OF INTEGRATED ENGINEERING VOL. 13 NO. 4 (2021) 208-216

IJIE

Journal homepage: http://penerbit.uthm.edu.my/ojs/index.php/ijie
ISSN : 2229-838X e-ISSN : 2600-7916

The International Journal of Integrated Engineering

Optimisation of Composite Briquette Made From Sawdust / Rice Husk Using Starch and Clay Binder

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DOI: https://doi.org/10.30880/ijie.2021.13.04.019
Received 30 January 2019; Accepted 17 December 2020; Available online 30 April 2021

Abstract: Upper limb spasticity (ULS) is a common pathophysiological changes manifest by a structural damage towards the central nervous system (CNS) that includes brain and spinal cord. The current clinical practice of spasticity assessment utilizes Modified Ashworth Scale (MAS) as a subjective tool to measure the severity of spasticity. Lack of objective value, poor sensitivity in detecting minimal changes, and dependency to the interpretation by the assessing clinicians are the several reasons of the inter and intra-rater variability of the measurement using MAS. These limit the use of MAS in diagnosing, treating, and monitoring spasticity especially in inexperienced clinicians, hence leading to inadequate spasticity management. To overcome this problem, a study is carried out to quantify and develop a data-driven model of ULS detection based on MAS. The characteristics that detect the existence of ULS according to MAS are identified and adopted to train the machine learning models for smart diagnosis purpose to assist the physicians to effectively manage spasticity.

Keywords: Upper limb spasticity, data-based model, smart diagnosis, Modified Ashworth Scale, machine learning

1. Introduction

To find low-cost methods of processing residue materials into usable items, the world has now gone deep into science. The explanation is the rising energy demand and the high energy content of these residue materials. One of the main rural-urban environmental issues in developing countries is the production of agricultural residue [1][2]. Numerous tonnes of agricultural residue are produced annually in Nigeria; sugar cane bagasse, rice husk, maize stalk, groundnut shell, palm kernel shell, etc., which pose an environmental hazard and result in air pollution when burnt-off [3][4][5]. Maybe some of these agricultural residue can be used and they have values [6][7]. It is possible to turn agricultural processing of these residue into useful products; briquettes that provide essential domestic energy replacement sources (i.e., cooking fuel). Of the world's 7.63 billion population, about 3 billion are expected to rely on kerosene, wood, coal and biomass for domestic cooking [5]. It is possible to turn wood waste, coaldust, and agricultural by-products into lofty energy briquettes for drying and cooking [4][9].

Many people around the world are very much in demand for biomass itself [10][11]. Biomass was found to be an alternative energy that could substitute fossil fuels in the future [12]. Biomass fuel exploits; composite sawdust and briquettes have been established as a high-quality renewable energy base for household cooking [13][14]. The large variety of briquettes used varies from household to industrial and for high-pressure briquettes, the most excellent materials are sawdust, rice husk and woody residues [15][16] since they have a high percentage of lignin. However, if grounded into an uncouth powder [17][18], the majority of parched agricultural residues can be used. When combined with woody biomass, some make a strong briquette to give lignin [19].

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At the same time as a fuel source, the importance of sawdust along with rice husk cannot be overstated as it is readily available and economical [15]. It is most commonly discarded or scalded off at sawmill sites in Nigeria, so a lot of energy is wasted and heat produced unrestrained [5][15]. Over the years, sawdust has been used to promote heat and power production in the gasification of plants and for household cooking [20]. This chance strengthens the question of how superlative the usage of this economic waste is [9]. This paper therefore analyzed and optimized the energy values of the various compressions created by the processing of rice husk and sawdust briquettes. However, before quantifying the energy values of the sawdust briquettes, a study of the binders for the various briquettes was carried out.

2. Materials and Methods

2.1 Materials

Rice husk and sawdust (mahogany, oak, gmelina arborea) are the materials used. These materials were obtained from Ugboka Rice Mill and Timber Wood Shop, Enugu, Nigeria. Clay and cold water starch were the binders used.

2.2 Methods

2.2.1 Raw Materials Preparation

The rice husk and sawdust were arbitrarily obtained at Ugboka and Timber, Enugu, Nigeria, from sawmills. Before briquette, the percentage moisture content of rice husk and sawdust are presented in Table 1. The moisture content was dried for about 50 minutes at a temperature range of 50-100 ºC. The samples were sieved at the range of 0.5 - 0.8mm sieve particle scale. For the various woods, rice husk, and 10 per cent for binder, the sample percentage weight was estimated at 90 per cent. For the experiments, twelve (12) separate samples were set up; six (6) of them for each binder (starch and clay) were Gmelina, oak, mahogany, Gmelina/mahogany/oak, rice husk, rice husk/Gmelina. Samples of starch and clay as binder, respectively, are Group A and Group B.

Table 1 - Moisture content before briquette

Moisture Content	Rice Husk	Sawdust
Before Drying	20 wt.%	15 wt.%
After Drying	5 wt.%	5 wt.%

2.2.2 Sawdust Briquettes Energy Content

The briquettes produced were sun-dried for approximately 2 days and the average mass was determined for each group sample. The average mass of the group sample was collected. In evaluating the calorific value of the briquettes, the Bomb Calorimeter was used. The calorific values of the briquettes were measured using the oxygen bomb calorimeter as per the ASTMD-240 standard.

2.3 Performance Analysis of Briquette

The suggested method for the determination of ignition and burning time by Rotich[21] was adopted and the method for the determination of the boiling water test by Kaur et al[22] was used. The burning rate, the cooking efficiency and the rate at which the briquettes of different fuel samples were burned were calculated using the Okwu et al[23] method.

2.4 Optimisation of Galvanized Energy of Biomass Briquettes

Using the Design Expert Program, optimization of the galvanized energy of biomass briquettes was achieved. A second order (quadratic) model was achieved using central composite design (CCD), an experimental design in response surface methodology (RSM). The design resulted in twenty (20) runs with the Binder proportion, the compaction pressure and the rice husk proportion as the independent variables and the biomass briquettes' galvanized energy as the response. In order to estimate a successful estimation of errors, five replications of centre points were used and experiments were conducted in a randomized order. The actual and coded levels of each factor are shown in Table 2. The coded values were designated by −1 (minimum), 0 (centre), +1 (maximum), −α and +α. The empirical equation is represented as shown below:

$$Y = \beta_0 + \sum_{i=1}^{3} \beta_i X_i + \sum_{i=1}^{3} \beta_{ii} X^2{}_i + \sum_{i=1}^{3} \sum_{j=i+1}^{3} \beta_{ij} X_i X_j \ldots\ldots \quad (1)$$

Table 2 - Factors for Central Composite Design for Briquette Production

Factor	Units	Low level	High level	-α	+α	0 level
Binder proportion (A)	%	10(-1)	20(+1)	5(-2)	25(+2)	15
Pressure (B)	MPa	6(-1)	12(+1)	3(-2)	15(+2)	9
The proportion of rice husk, RH	%	20(-1)	40(+1)	10(-2)	50(+2)	30

3. Results and Discussion

3.1 Statistical and optimisation of the Energy value of Biomass Briquette Produced from Mahogany Sawdust/rice husk Composite with Starch Binder

For the statistical analysis and optimization of the energy value of biomass briquettes produced from sawdust/rice husk composites using various binders (clay and starch), the design plan in Table 3 was used. The coded and encoded values of the test variables were used to optimize the variables; binder proportion, compaction pressure and proportion of rice husk to the energy value.

Table 3 - Result of experimental design matrix for optimisation of galvanized energy

Std	A: Binder proportion	B: Compaction pressure	C: Proportion of RH	GE for Clay	GE for Starch
	%	MPa	%	kcal/g	kcal/g
1	10	6	20	2.29	3.30
2	20	6	20	3.54	4.75
3	10	12	20	3.00	4.90
4	20	12	20	2.90	3.50
5	10	6	40	2.30	2.50
6	20	6	40	3.14	4.20
7	10	12	40	3.30	4.30
8	20	12	40	2.60	3.20
9	5	9	30	1.73	3.30
10	25	9	30	2.50	3.60
11	15	3	30	2.92	2.60
12	15	15	30	3.10	3.20
13	15	9	10	3.20	3.90
14	15	9	50	2.80	2.70
15	15	9	30	3.30	5.70
16	15	9	30	3.08	5.60
17	15	9	30	3.30	5.66
18	15	9	30	3.30	5.60
19	15	9	30	3.35	5.60
20	15	9	30	3.30	5.70

The energy value depends on the significance of the variance of the outcomes from combinations of process parameters. In Equation 2, the quadratic regression equation built from the program is shown. This equation provides the optimum value of energy by comparing it to coded value variables.

$$Y = 5.64 + 0.078A + 0.15B - 0.29C - 0.71AB + 0.069AC + 0.056BC - 0.55A^2 - 0.69B^2 - 0.59C^2 \qquad (2)$$

The quadratic model illustrates how the response (energy value, GE) is influenced by the three variables (A, B and C). It consists of one factor and multi-factor coefficients, which, respectively, give the effect of a single factor and the combined effect of various factors. Synergistic and antagonistic effects are described respectively by positive and negative expressions. The sequential model sum of squares from Table 4 gave a broad model F-value of 1939.97, which justifies the adequacy of the proposed quadratic model. The statistics test gave a high regression coefficient, R^2 =

0.9994 with a modified R^2 value of 0.9989, which is similar to the expected R^2 value of 0.9986, to confirm the adequacy of the model. The CV obtained was 0.91 per cent. Since 116.979 'Adeq Precision' is greater than 4, the signal is therefore sufficient, so the model can traverse the design room.

Table 4 - Significance of regression coefficients of energy value for sawdust/rice husk briquettes with a starch binder.

Source	**Degree of freedom**	**Sum of square**	**Mean Square**	**F-value**	**P-value (Prob >F)**
Model	9	25.56	2.84	1939.97	< 0.0001
A	1	0.098	0.098	66.71	<0.0001
B	1	0.35	0.35	235.79	< 0.0001
C	1	1.35	1.35	926.21	< 0.0001
AB	1	3.99	3.99	2725.98	< 0.0001
AC	1	0.038	0.038	25.83	0.0005
BC	1	0.025	0.025	17.29	0.002
A^2	1	7.54	7.54	5150.86	< 0.0001
B^2	1	11.80	11.80	8062.25	< 0.0001
C^2	1	8.61	8.61	5880.46	< 0.0001
Residual	**10**	**0.015**	0.00146		
Lack of fit	**5**	**0.00231**	0.00461	0.19	0.9553
Cor. Total	**19**	**25.57**			

Std. Dev. = 0.038; Mean = 4.19; C.V.% = 0.91; PRESS = 0.036; R^2 = 0.9994; Adj. R^2 = 0.9989; Pred. R^2 = 0.9986; Adeq. Precision = 116.979

It can be seen from Table 4 that the terms A, B , C (linear terms), AB, AC, BC (interactive terms) and A^2, B^2, C^2 (quadratic terms) are critical when applying the 5 per cent significance level for the analysis of variance (ANOVA), so the model terms are retained.

In Figure 1, the actual and predicted plot gives the association between the expected energy value and the energy value of the experiment. The near distribution of the points along the straight line shows agreement between the values of the experimental and projected responses and appropriate assumptions for the study, thus justifying the established quadratic model.

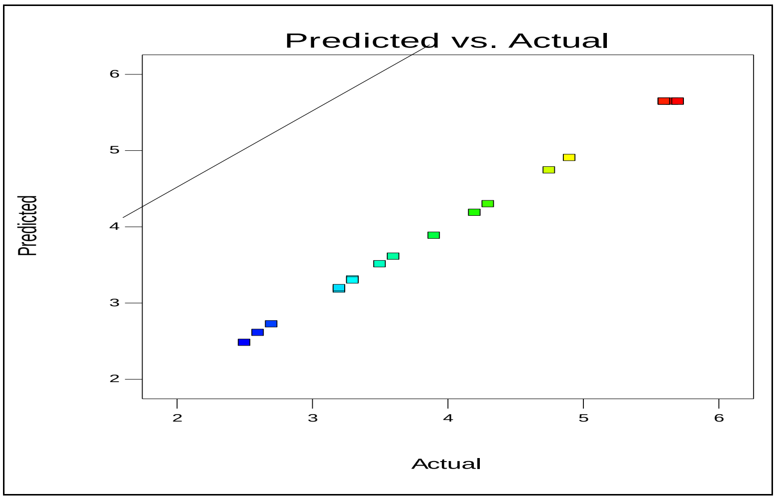


Fig. 1 - Predicted against actual experimental values for energy value (sawdust/rice husk briquettes with starch binder)

The contours and 3D surface plots are shown in Figures 2, 3 and 4. They explain how the energy value is influenced by combining two independent variables. The combined effect of binder composition and compaction pressure on the energy value is shown in Figure 2. It shows that as pressure and binder proportion increased, the energy value increased until it began to decrease at a point. This may be due to greater binder proportion and pressure [15].

The interactive effect of the rice husk proportion and the binder proportion on the energy value is shown in Figure 3. It could be seen that as both rice husk and binder proportions increased, the energy value increased until it began to decrease at a point. The interaction effect of the rice husk proportion and the compaction pressure on the energy value is shown in Figure 3. It indicates that as both rice husk proportions and compaction pressure increased, the energy value increased until it began to decrease at a point. This may be due to higher rice husk and compaction pressure proportions as shown in Table 5.

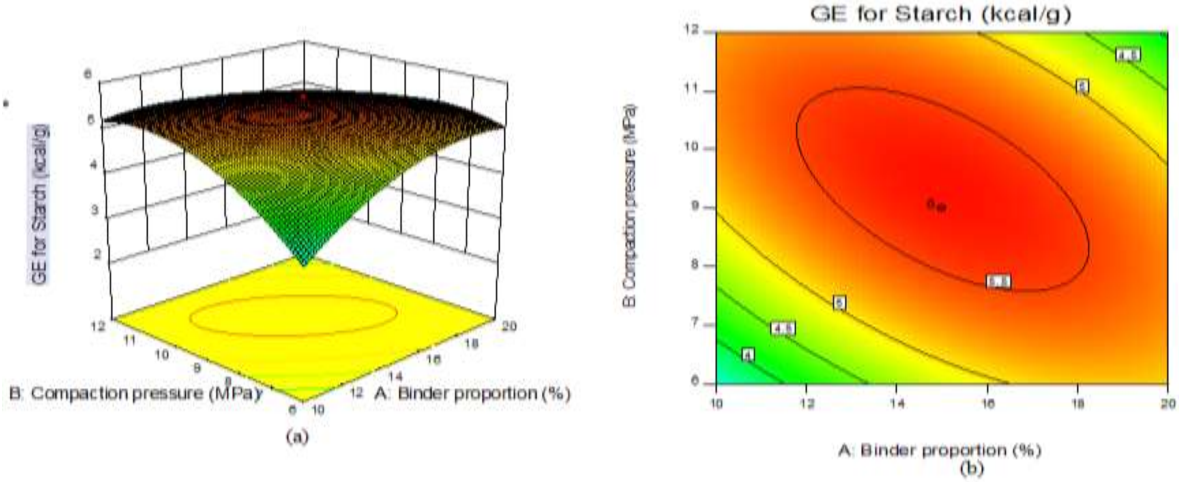


Fig. 2 - Interaction Effects of factors binder proportion and compaction pressure (a) Response surface 3D plot (b) Contour plot

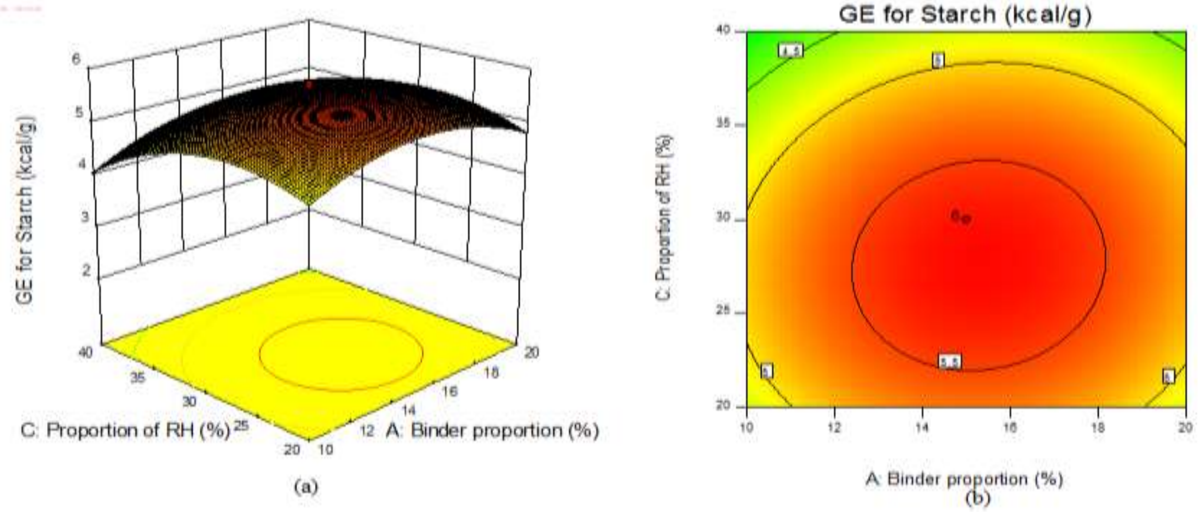


Fig. 3 - Interaction effects of factors binder proportion and proportion of rice husk and binder proportion (a) Response surface 3D plot (b) Contour plot

The optimization process gave an optimum 15 per cent binder percentage of 5.69 kcal/g energy, 28 per cent rice husk percentage, and 9 MPa compaction pressure. However, by carrying out a validation experiment to evaluate the rationale of the predicted optimum values, the experimental outcome was 2 per cent lower than the predicted value, so the evolved quadratic model is adequate to predict the energy value.

Table 5 - Model validation for energy value of composite briquette produced with a starch binder (experiment to validate the optimum energy value)

Binder proportion (%)	Compaction pressure(MPa)	The proportion of rice husk(%)	Experimented energy value	Predicted energy value
A	B		(kcal/g)	(kcal/g)
15	9.3	28	5.51	5.69

3.2 Statistical and optimisation of the Energy value of Biomass Briquette Produced from Mahogany Sawdust/rice husk Composite with Clay Binder

The energy value of the biomass briquette generated from mahogany sawdust/rice husk composite with clay binder was analysed and optimized using the design plan shown in Table 3. The quadratic model shown in Equation 3 was induced by the optimization of the variables.

$$Y = 3.28+0.18A+0.056B-0.074C-0.36AB-0.13AC+0.049BC-0.29\boldsymbol{A}^2-0.062\boldsymbol{B}^2-0.065\boldsymbol{C}^2 \qquad (3)$$

The quadratic model illustrates how the response (energy value, GE) is influenced by the three variables (A, B and C). It consists of one factor and multi-factor coefficients, which, respectively, give the effect of a single factor and the combined effect of various factors. Synergistic and antagonistic effects are described respectively by positive and negative expressions. The sequential model sum of squares from Table 6 gave a broad model F-value of 59.95, which justifies the adequacy of the proposed quadratic model. The statistics test gave a high regression coefficient, R^2 = 0.9818 with a modified R^2 value of 0.9654, which is similar to the expected R^2 value of 0.9309, for validation of the adequacy of the model. The obtained CV was 2.88 percent. Since the 'Adeq Precision' of 30.27 is greater than 4, the signal is therefore adequate; the model can therefore be used to traverse the design space.

Table 6 - Significance of regression coefficients of energy value for sawdust/rice husk briquettes with a clay binder

Source	**Degree of freedom**	**Sum of square**	**Mean Square**	**F-value**	**P-value (Prob >F)**
Model	9	3.89	0.43	59.95	< 0.0001
A	1	0.50	0.5	69.49	< 0.0001
B	1	0.05	0.05	6.87	0.0255
C	1	0.089	0.089	12.29	0.0057
AB	1	1.04	1.04	144.93	< 0.0001
AC	1	0.13	0.13	17.70	0.0018
BC	1	0.019	0.019	2.64	0.1353
A^2	1	2.06	2.06	285.55	< 0.0001
B^2	1	0.098	0.098	13.54	0.0043
C^2	1	0.11	0.11	14.64	0.0033
Residual	**10**	**0.072**	0.0072		
Lack of fit	**5**	**0.026**	0.00519	0.56	0.7281
Cor. Total	**19**	**3.96**			

Std. Dev. = 0.085; Mean = 2.95; C.V.% = 2.88; PRESS = 0.27; R^2 = 0.9818; Adj. R^2 = 0.9654; Pred. R^2 = 0.9309; Adeq. Precision = 30.27

It can be shown from Table 6 that the terms A, B , C (linear terms), AB, AC (interactive terms) and A^2, B^2, C^2 (quadratic terms) are important by applying the 5 percent significance p-value standard for the study of variance (ANOVA), thus reducing the model to Equation 4.

$$Y = 3.28 + 0.18A + 0.056B - 0.074C - 0.36AB - 0.13AC - 0.29\boldsymbol{A}^2 - 0.062\boldsymbol{B}^2 - 0.065\boldsymbol{C}^2 \qquad (4)$$

In Figure 4, the real and expected plot gives the correlation between the expected energy value and the energy value of the experiment. The near distribution of the points along the straight line shows agreement between the values of the experimental and projected responses and appropriate assumptions for the study, thus justifying the established quadratic model.

In the contour and 3D surface plots shown in Figures 5 and 6, the combined effect of two independent variables at a time on the energy value is expressed. Figure 5 shows the interaction effect of the binder proportion and compaction pressure on the energy content of sawdust/rice husk briquettes manufactured with clay as a binder. It shows that as both the pressure and the binder proportion increased, the energy value increased until it began to decrease at a point. The interaction effect of rice husk proportion and binder proportion on the energy value of mahogany sawdust/rice husk briquettes produced with clay as a binder is shown in Figure 6. It shows that as both the proportion of rice husk and binder proportion increased, the energy value increased until it began to decrease at a point. Higher proportions of rice husk may be due to this.

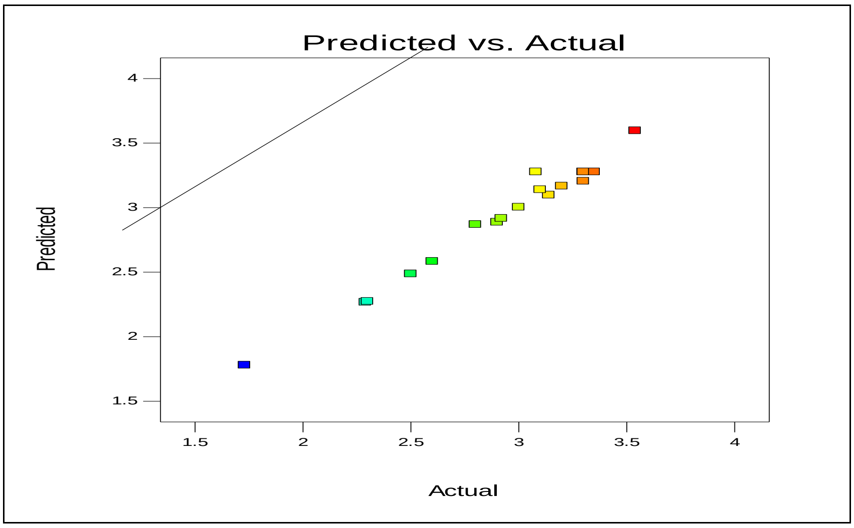
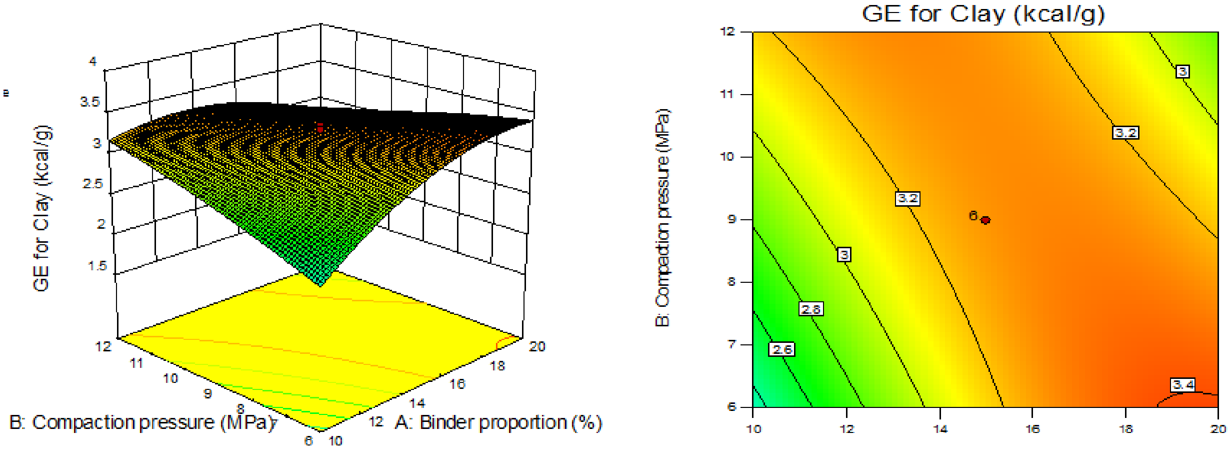


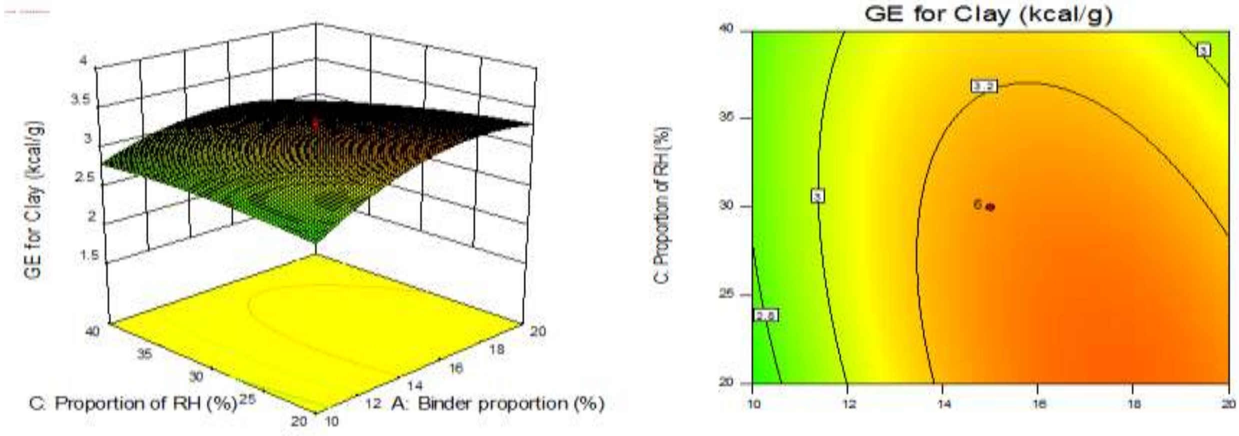
Fig. 4 - Predicted values versus the actual experimental values for energy value sawdust/rice husk briquettes with a clay binder



(a)

(b)

Fig. 5 - Interaction effects of factors binder proportion and compaction pressure (a) Response surface 3D plot (b) Contour plot



(a)

(b)

Fig. 6 - Interaction effects of factors binder proportion and proportion of rice husk and binder proportion. (a) Response surface 3D plot (b) Contour plot

At an optimum 17 percent binder proportion, 26 per cent rice husk proportion and 9MPa compaction pressure, the optimization process gave an energy of 3.35kcal/g. However, the experimental outcome was lower than the predicted value by 2 per cent by carrying out a validation experiment to evaluate the basis of the predicted optimum values as shown in Table 7, so that the established quadratic model is adequate to predict the energy value.

Table 7 - Results of the model validation for energy value of composite briquette produced with clay binder (experiment to validate the optimum energy value)

Binder proportion (%) A	Compaction pressure(MPa) B	The proportion of rice husk	Experimented energy value (kcal/g)	Predicted energy value (kcal/g)
17	9	26.389	3.30	3.35

Table 8 - Performance Analysis of Mahogany Sawdust/Rice Husk Composite Briquette

Samples	**Ignition Time**	**Burning Time**	**Boiling Time**	**Burning Rate**	**Fuel Consumption**	**Efficiency**
MAHOGANY/RICE HUSK (A)	0.2	45.51	17.2	0.037	31.1	46.7
MAHOGANY/RICE HUSK (B)	0.222	38.21	18.5	0.042	34.12	42.4

Table 8 shows that mahogany sawdust/rice husk composite bonded with starch at optimum conditions of 9 Mpa, 15 per cent binder and 28 per cent rice husk have a low ignition time of 0.2 minutes, a high ignition time of 45.51 minutes, a low boiling time of 17.2 minutes, a low burning rate of 0.037 g/minute, a low fuel consumption of 31.1 g/minute and a high cooking efficiency of 46.7 per cent compare to other briquettes [24][25]. These performance parameters show that composite briquette made from mahogany sawdust and rice husk blended with starch is better compared to when separated because the boiling time and the burning rate are lower than others which help to achieve a higher efficiency of 46.7 per cent. The result is also better than the briquette provided by Olatunde et al[24] using a groundnut shell and the difference may be due to the composite although similar to Chinyere et al[25].

4. Conclusion

Generally, biomass briquettes have shown strong prospects as a potential fuel source. The optimization of sawdust (mahogany)/rice husk composite briquettes' energy values using starch and clay as binder was performed using Response Surface Methodology (RSM), after which the optimal condition values (15 per cent starch, 28 per cent rice husk and 9 Mpa compaction pressure) were used to create a composite briquette made from mahogany sawdust/rice husk). The results showed that the energy value of mahogany sawdust and rice husk composite briquettes produced using starch was 5.69 kcal/g higher than that of clay (3.35 kcal/g). This shows that briquette is therefore more suitable for starting and sustaining fire for cooking and other domestic heating from composite sawdust (Mahogany)/rice husk, so it was noted that starch is a better medium for bonding than clay.

References

[1] Yazdani, M. G. & Hosam M. A. (2010). Properties of Briquette from Agricultural Waste available in Brunei Darussalam and its Environmental Impact. International Scientific Journal, 1–8

[2] Chukwuneke J. L., Azaka O. A., Chukwujike I. C., & Sinebe J. E. (2016). Optimisation of Waste Management System in Anambra State: A case study of Ifite-Awka. American Journal of Engineering Research, 5(8), 138–151

[3] Achebe C. H., Obika E. N., Chukwuneke J. L. & Ani OI. (2019). Optimisation of hybridised cane wood-palm fruit fibre frictional material. Proc IMechE Part L. J Materials: Design and Applications, 233 (12), 2490–2497. Doi: 10.1177/1464420719863445

[4] Imeh E. O., Ibrahim A. M., Aleivo O. A., Stanley I. R. O., & Opeoluwa O. F. (2017). Production and Characterisation of Biomass Briquettes from Tannery Solid Waste. Recycling, 2(17), 1– 19

[5] Babajide P. A., Akinrinnola T. B., Oyeiola Y. B., Okoro-Robinson M. O., Salami T. B., Adesina A., & Akindeere A. A. (2018). Performance of Maize (Zea Mays) Grown on Mildly Acidic low Fertile Soil as Affected by Selected Organic-Based Soil Amendments and Synthetic Fertiliser. International Journal of Research-Granthaalayah, 6(9), 385–394

[6] Arevalo P. A., Baggethun E. G., Lopez B. M., & Rincon M. P. (2018). Wiedning the evaluative space for ecosystem services: A taxonomy of plural values and valuation methods. Environmental values, 27(1), 29–53

[7] Chukwuneke J. L., Ewulonu M. C., Chukwujike I. C., & Okolie P. C. (2019). Physico-chemical analysis of pyrolysed bio-oil from Swietenia Macrophylla (mahogany) wood. Heliyon, 5, e01790. doi.org/10.1016/j.heliyon.2019.e01790

[8] Chukwuneke J. L., Sinebe J. E., Ugwuegbu D. C. & Agulonu C. C. (2016). Production by Pyrolysis and Analysis of Bio-oil from Mahogany Wood (Swietenia Macrophylla). British Journal of Applied Science & Technology, 17(4), 1–9

[9] Akande O. M. & Olorunnisola A. O. (2018). Potential of Briquetting as a Waste-management Option for Handling Market-Generated Vegetable Waste in Port Harcourt, Nigeria. Recycling, 3(2), 11

[10] Zannikos, F. E., Kalligeros S., Anastopoulos G., & Lois E. (2012). Converting Biomass and Waste Plastic to Solid Fuel. Journal of Renewable Energy, doi.org/10.1155/2013/360368, 1 – 9

[11] Wilyanto A. S., Fandi D. S., & Jovian E. (2017). Biomass Briquette Investigation from Pterocarpus Indicus Leaves Waste as an Alternative Renewable Energy. IOP Conf. Series: Materials Science and Engineering, 241, 012043. DOI:1088/1757-899X/241/1/012043

[12] Nasir V., Nourlan S., Avramidis S., & Cool J. (2018). Classification of thermally treated wood using Machine learning techniques. Wood Science and Technology, doi.org/10.1007/500226-018-1073-3

[13] Aina, O. M., Adetogun, A. C., & Iyiola, k. A. (2009). Heat energy from valued-added sawdust briquettes of AlbiziaZygia. Ethiopia journal of environmental studies and management, 2(1), 42 -49

[14] Emerhi, E. A. (2011). Physical and combustion properties of briquettes produced from sawdust of three hardwood species and different organic binders.Advances in Applied Science Research, 2 (6), 236-246

[15] Achebe C. H., Umeji A. C., Chukwuneke J. L. (2018). Energy Evaluation of various Compositions of Biomass Waste Briquettes. Advances in Research, 13(6), 1–11

[16] Abdulrasheed A., Aroke U. O. & Ibrahim M. (2015). Compression Pressure Effect on Mechanical & Combustion properties of Sawdust Briquette using Styrofoam adhesive as a binder. American Journal of Engineering Research, 4(8), 205-211

[17] Oladeji, J. T. (2012). Comparative Study of Briquetting of Few Selected Agro-Residues Commonly Found in Nigeria.Journal of Science and Technology, 13(2). 1

[18] Onuegbu T. U., Ogbu L. M. & Ejikeme C. (2012). Comparative Analyses of Densities and Calorific Values of Wood and Briquettes Samples Prepared at Moderate Pressure and Ambient Temperature.International Journal of Plant, Animal and Environmental Sciences, 2(1), 40-45

[19] Raju A. I., Praveena U., Satya M., Jyothi K. R. & Sarveswara S. (2014). Studies on Development of Fuel Briquettes using Biodegradable Waste Materials. Journal of Bioprocessing and Chemical Engineering, 2(1). 1

[20] Shekhar, N. (2011). Popularisation of Biomass Briquettes- A means for Sustainable Rural Development. Asian Journal of Management Research, 2(1), 457 – 473

[21] Rotich P.K. (1996). Carbonization and Briquetting of Sawdust for use in Domestic Cookers. *M.Sc. Thesis, Department of Agricultural Engineering, University of Nairobi, Kenya*

[22] Kaur A., Kumar A., Singh P., Kundu K. (2017). Production, Analysis and Optimization of low-cost Briquettes from Biomass Residues. *Advances in Research*, 12(4): 1 – 10.

[23] Okwu M.O., Samuel O.D., Emovon I. (2018). Production of fuel Briquettes from Hybrid Waste (Blend of Saw-dust and Groundnut shell). *Journal of Mechanical Engineering and Technology*, 10(2): 1 – 14

[24] Olatunde A.O., Bukola O.B., Mufutau A.W., Micheal F.A. (2015). Performance Evaluation of Effect of Waste Paper on Groundnut Shell Briquette. *Int. Journal of Renewable Energy Development 4 (2): 95 – 101*

[25] Chinyere D.C., Asoegwu S.N., Nwandikom G.I. (2014). An Evaluation of Briquettes from Sawdust and Corn Starch Binder. *The International Journal of Science & Technology*, 2(7): 147 – 157