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# Optimising the effects of Additives and Briqetting on the Calorific Values of Oilpalm Fiber Using Response Surface Methodology

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**Abstract**

Thirty grammes (30gms)of oil palm fiber were mixed with three different weights of sawdust and slurry oil (5,10,and 15gm) respectively, dried and compacted to three bulk density levels of 1.86,2.0,and 2.14g/ml with a briquetting machine. Calorific values of the samples were determined using a bomb calorimeter. (Model XRY-1A). The experimental design used was Response Surface Methodology, exploring the effects of the three levels of the three factors of quantity of sawdust, slurry oil and compaction density of the oil palm fiber on the calorific values of the samples. The factors that affected the calorific yield of the oil palm fiber are the linear and quadratic effects of the quantity of slurry oil added to the mixture. This factors accounted for about 92.2% of the variation in effects. Also the linear and quadratic effects of compacted density were significant at 5% probability levels.

**Keywords**; Oilpalm,Fiber, Briquets ,Response, Surface, Methodology

## Introduction

Oil palm fiber is a form of biomass. Oil palm (*elaies guinesis*) is an oil bearing tree commonly found in the tropics. Nigeria generates a lot of waste from biomass, a renewable energy resource, and an alternative energy source to the combustible fossil fuel, which is fast depleting. This source of energy has not been fully exploited. Thus, given the growing world population, increasing energy demand per capita and global warming, the need for a long term alternative energy supply is an imperative (Ohunakin, 2010). Apart from the introduction of efficient and clean thermal use of traditional biomass for cooking, the provision of electricity from renewable waste resources can provide basic energy services for lighting, communication and promote local economic growth (Sambo , 2009).

The Calorific Value, or amount of heat available in a fuel (kJ/kg), is one of the most important characteristics of a fuel because it indicates the total amount of energy that is available in the fuel (Agba *et al.*, 2010). The Calorific Value in a given fuel type is mostly a function of the fuel's chemical composition. The Calorific Value of a fuel indicates the energy available in the fuel per unit mass – MJ/kg (BTU/lb) (Demirbas, 2004). Biomass for energy, especially biofuels, has positive attributes that contribute to a healthy environment and economy. Biomass offers important advantages as a combustion feedstock due to the high volatility of the fuel and the high reactivity of both the fuel and the resulting char. However, it should be noticed that in comparison with solid fossil fuels, biomass contains much less carbon and more oxygen and has a low Calorific Value (Demirbas 2004; Etoamaihe, 2015). Oil palm fibre is a byproduct derived from the processing of palm oil from oil palm bunches. Oil palm fibre has been used as a composite material for plywood, polymer, particle board and source of biofuel among other uses. Currently palm oil and fiber are mixed with coal in thermal power plants to produce electricity and heat (Kavalek *et al.*, 2013). With the increasing sales of boilers for biomass combustion worldwide, there is an expectation of growing consumption of solid biofuels (Mekhilef *et al.*, 2010).

The Response Surface Methodology (RSM) is important in designing, formulating, developing, and analyzing new scientific study and products. It is also efficient in the improvement of existing studies and products (Khuri and Cornell, 1996). The most common applications of RSM are in Industrial, Biological and Clinical Science, Social Science, Food Science, and Physical and Engineering Sciences. According to Myers and Montgomery (2002), RSM method was introduced by Box and Wilson ( 1951). They suggested the use of a first-degree polynomial model to approximate the response variable. They acknowledged that this model is only an approximation, but such a model is easy to estimate and apply, even when little is known about the process. Response Surface Methods are designs and models for working with continuous treatments when finding the optima or describing the response (Agriga and Iwe 2008 and www.Sciencedirect.com 2019). The first goal for Response Surface Method is to find the optimum response. When there is more than one response then it is important to find the compromise optimum that does not optimize only one response (Jau *et al.*, 2009). When there are constraints on the design data, then the experimental design has to meet requirements of the constraints. The second goal is to understand how the response changes in a given direction by adjusting the design variables. In general, the response surface can be visualized graphically. The graph is helpful to see the shape of a response surface; hills, valleys, and ridge lines

(Kathleen *et al*., 2004). According to Deniz and Ismail (2007), RSM is the most popular optimization method used in recent years because of the ease of application and least number of experimental runs needed to evaluate a process, www.Intechopen.com (2019).

General objective of this research is to optimize the effects additives and briquetting on the calorific value of palm oil fiber using Response Surface Methodology.

Specific Objectives are;

(i) To determine the calorific value of palm oil fiber when varied densities of the biomass material and varied quantities of slurry (condemned) oil is added and homogenous mixing of saw dust at different levels.

(ii) To compare and statistically analyze the response of each varied factor on the calorific value obtained from each biomass sample using Response Surface Methodology.

**Materials and Methods**

Palm oil fiber was obtained from a palm oil processing mill located in Uzuakoli, Bende Local Government Area of Abia State. The slurry oil (spent oil) used was obtained from the Engineering Workshop, Michael Okpara University of Agriculture, Umudike and the sawdust (wood shavings) used was obtained from a saw mill located at Ahiaeke, Umuahia, Abia State. Palm oil fiber were mixed with different ratios of wood shavings and slurry oil. In each case 30gms of oil palm fiber was used. The samples were properly dried in a hot air oven at 80 degrees Centigrade for 24 hours. The resulting samples were compacted to three different bulk density levels using a briquetting machine after which their calorific values were determined using a Digital Displays Oxygen Bomb Calorimeter (XRY-1A).

**Experimental Design and Statistical Analysis**

A three factor, three level central composite design of RSM was used in this study. This design is suitable for exploration of quadratic response surfaces and construction of a second order polynomial model thus helping in optimizing the process using a small number of experimental runs,( Stewart *et al*.,2002). A total of 20 experimental runs were used. The nonlinear model of the R S M is:

$$Y = bo + \sum_i biXi + \sum_i biiXi^2 + \sum \sum_{ik(k\angle j)} bjkXjXk \quad (1)$$

Where *Y*= response variable

*bo*= intercept

*Xk, Xj, Xi* = independent variables.

*bii, bjk, bi*= regression coefficients of the model.

The experimental design, regression analysis and response surface graphs were carried out with Matlab 7.1 software.

- A faced central composite design for k=3 was employed to study the linear, interactive and quadratic effects of the independent experimental variables (Nist/Sematech, 2012). The experimental variables were of three levels, and the experimental designs with coded terms are shown in Table 1. These factors are described as follows:
- Three different quantities of slurry oil, namely; (i) 5g (ii) 10g (iii) 15g
- Three different quantities of sawdust, namely; (i) 5g (ii) 10g (iii)15g
- Three different levels of compaction in densities, namely; (i) 1.86g/ml (ii) 2.00g/ml (iii) 2.14g/ml
- The response investigated was the calorific value obtained from each experimental run. The faced central composite design requires 20runs for the total analysis of the experimental result (Nist/Sematech, 2012). The response surface analysis used was faced centered, central composite design with 3 factors at three levels with 6 centre points and 20 runs.

These factors were coded as required in central composite design.

The coding is as follows;

1= highest factor

0= medium factor

-1=lowest factor

For the experiment, the coding is as follows;

i. Quantity of slurry oil ($x_1$); 1= 15g, 0=10g,-1=5g
ii. Quantity of saw dust ($x_2$); 1=15g, 0=10g, -1=5g
iii. Compaction density of the oil palm fiber ($x_3$); 1=2.14g/ml, 0=2.00g/ml, -1=1.86g/ml.

**Table 1: Experimental Variables Used in the Central Composite Design (k=3) for the Experiments.**

| **Independent Variables** | **Variable Levels** | | |
|---|---|---|---|
| Quantity of slurry oil (g)$X_1$ | 15 | 10 | 5 |
| Quantity of saw dust (g)$X_2$ | 15 | 10 | 5 |
| Density of palmoil fiber (g/ml) $X_3$ | 2.14 | 2.0 | 1.86 |
| Code designation | 1 | 0 | -1 |

**Results and Discussions**

The experimentally obtained results of the varied factors on the coded terms are shown on Table 2.

**Table 2: Experimental Result Data of Varied Factors and Calorific Yield Value in Coded Terms**

| Runs | Quantity of slurry oil (g) | Quantity of sawdust (g) | Compacted density (g/ml) | Calorific yield value (MJ/Kg) |
|---|---|---|---|---|
| 1 | -1 | -1 | -1 | 23.09 |
| 2 | +1 | -1 | -1 | 17.36 |
| 3 | -1 | +1 | -1 | 21.74 |
| 4 | +1 | +1 | -1 | 6.79 |
| 5 | -1 | -1 | +1 | 16.57 |
| 6 | +1 | -1 | +1 | 9.54 |
| 7 | -1 | +1 | +1 | 17.40 |
| 8 | +1 | +1 | +1 | 6.73 |
| 9 | -1 | 0 | 0 | 21.90 |
| 10 | +! | 0 | 0 | 3.23 |
| 11 | 0 | -1 | 0 | 21.54 |
| 12 | 0 | +1 | 0 | 13.25 |
| 13 | 0 | 0 | -1 | 23.42 |
| 14 | 0 | 0 | +1 | 18.82 |

| | | | | |
|---|---|---|---|---|
| 15 | 0 | 0 | 0 | 16.66 |
| 16 | 0 | 0 | 0 | 18.43 |
| 17 | 0 | 0 | 0 | 18.25 |
| 18 | 0 | 0 | 0 | 17.87 |
| 19 | 0 | 0 | 0 | 17.65 |
| 20 | 0 | 0 | 0 | 18.30 |

The regression equation obtained is given as:

Y = 17.9 - 5.70 X1 - 2.22 X2 - 2.33 X3 - 5.46 X1^2 - 0.63 X2^2 + 3.09 X3^2 - 1.61 X1*X2 + 0.373 X1*X3 + 1.24 X2*X3

The estimated regression coefficient and the analysis associated with the data analysis are as shown.

**Table 3: Regression Table of Calorific Values Versus Quantity of Surry Oil, Quantity of Sawdust and Compacted Density.**

| Predictor | Coef | St Dev | T | P |
|---|---|---|---|---|
| Constant | 17.9265 | 0.7560 | 23.71 | 0.000 |
| X1 | -5.7050 | 0.6954 | -8.20 | 0.000 |
| X2 | -2.2190 | 0.6954 | -3.19 | 0.010 |
| X3 | -2.3340 | 0.6954 | -3.36 | 0.007 |
| X1^2 | -5.461 | 1.326 | -4.12 | 0.002 |
| X2^2 | -0.631 | 1.326 | -0.48 | 0.644 |
| X3^2 | 3.094 | 1.326 | 2.33 | 0.042 |
| X1*X2 | -1.6075 | 0.7775 | -2.07 | 0.066 |
| X1*X3 | 0.3725 | 0.7775 | 0.48 | 0.642 |
| X2*X3 | 1.2425 | 0.7775 | 1.60 | 0.141 |
| S = 2.199 | R-Sq = 92.2% | R-Sq(adj) = 85.1% | | |

**Table 4: Analysis of Variance**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 9 | 569.893 | 63.321 | 13.09 | 0.000 |
| Error | 10 | 48.357 | 4.836 | | |
| Total | 19 | 618.250 | | | |

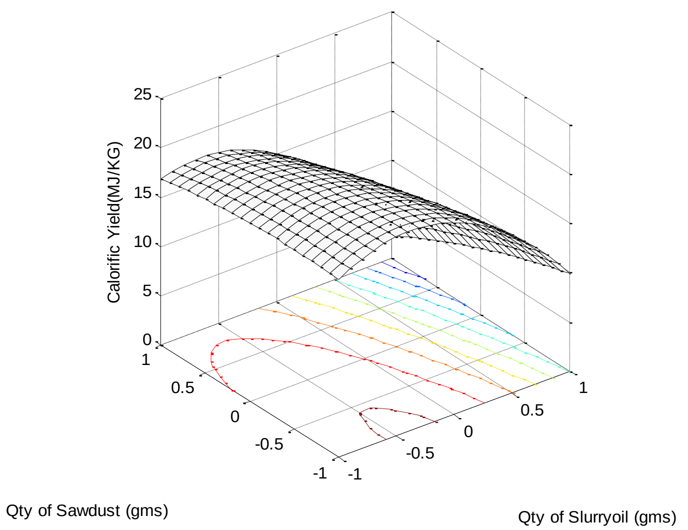


**Figure 1: Response Surface Curve of the Effect of Sawdust and Slurry Oil on the Calorific Value of Oil Palm Fiber.**

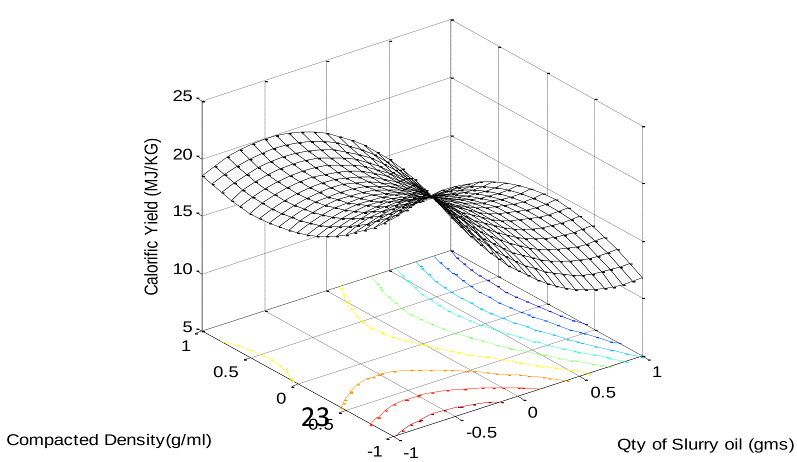

**Figure 2: Response Surface Curve of the Effect of Compacted Density and Slurry oil on the Calorific Value of Oil Palm Fiber.**

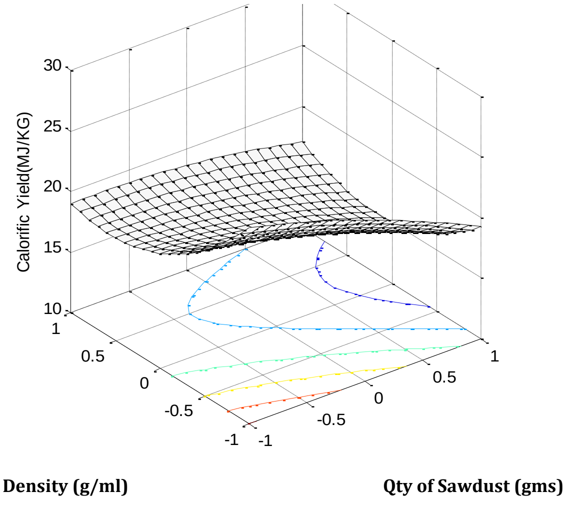


**Figure 3: Response Surface Curve of the Effect of Compacted Densities and Sawdust on the Calorific Value of Oil Palm Fiber.**

## Discussions Relating to the Calorific Values Obtained

Tables 3 and 4 show the results of the regression analysis and analysis of variance on the calorific values data obtained experimentally. The linear terms of $x_1$, $x_2$ and $x_3$ were only values that were significant ($P< 0.05$) on the calorific yield value.

The factors that affected the calorific yield of the oil palm fiber are the linear and quadratic effects of the quantity of slurry oil added to the mixture. These factors accounted for about 92.2% of the variation in effects. Also, the linear and quadratic effects of compacted density were significant. From Fig.1, the highest calorific value yield obtained was 17.5MJ/Kg when the quantity of sawdust was 12.5g and the quantity of slurry oil was 10g, while the lowest calorific value (10 MJ/Kg) was obtained when the quantity of slurry oil was 15g and quantity of saw dust was 5g. From Fig. 2, the highest overall calorific yield of 20MJ/Kg was obtained when the quantity of slurry oil was lowest (5g) and the compacted density was highest (2.14g/ml).The lowest calorific value yield (10.5MJ/Kg) was obtained when compacted density was 1.86g/ml and the quantity of slurry oil was 15g. In Fig. 3 the curve resembles a valley, with the highest calorific value of 19.1MJ/Kg obtained when the compaction density was 2.14g/ml and the quantity of sawdust was15g.While the lowest calorific value of 14.6MJ/Kg was obtained at 2.0g/ml compacted density and 7.5g quantity of sawdust.

## Conclusions

The factors that affected the calorific yield of the oil palm fiber were the linear and quadratic effects of the quantity of slurry oil added to the mixture. These factors accounted for about 92.2% of the variation in effects. Also, the linear and quadratic effects of compacted density were significant at 5% probability level. In general, the higher the compacted densities and quantities of sawdust added to the mixture, the higher the calorific value yield obtained from it, while the addition of more quantities of slurry oil to the mixture reduce the calorific value yield.

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