



Production of Biomass Briquettes Using Coconut Husk and Male Inflorescence of *Elaeis guineensis*

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Authors' contributions

This work was carried out in collaboration among all authors. Author OJL supervised the study and gives the idea, Author TAA performed the experiment, the preliminary analyses and read the first draft, author SOA managed the literature searches and give technical advice and author EAI proof-read the second manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The decreasing availability of fuel wood coupled with the increasing prices of kerosene and cooking gas in Nigeria has drawn attention on the need to consider alternative sources of energy for domestic and industrial use in the country. The study was undertaken to evaluate the combustion properties (percentage volatile matter, percentage ash content, percentage fixed carbon, heating value) of briquette produced from coconut husk and male inflorescence of *Elaeis guineensis*. The experiment was laid down using the Randomized Complete Block Design (RCBD). The study involves three particle sizes (2 mm each) of coconut husk, male inflorescence of oil palm tree and cassava starch used as binder. The coconut husk and male inflorescence of *Elaeis guineensis* were varied into (25:30:40:50:60) respectively and bound together with starch at same ratio. Proximate analysis was carried out to determine the constituent of the briquettes which include ash content, percentage fixed carbon, percentage volatile matter and experimental test to determine the heating

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value was also determined. All processing variables in this study were significantly different except for heating value at $P > 0.05$. From the result of the percentage ash content, briquette produced from coconut husk, male inflorescence and starch at (20:20:60) has the least fixed carbon (6.5%) with better performance. The highest percentage volatile matter 74.6% was obtained from coconut husk, male inflorescence and starch at (20:20:60) while low fixed carbon (18.8%) was obtained from male inflorescence and starch at (60:40). In conclusion, large quantities of wastes generated in terms of coconut husk and male inflorescence which are disposed indiscriminately can be utilized to produce briquette with enhanced performance.

Keywords: Biomass; briquette; coconut husk; inflorescence; *Elaeis guineensis*; fuel.

1. INTRODUCTION

The importance of energy especially renewable energy for a nation's development cannot be overemphasized and this is because energy is the cornerstone of economic and social development [1]. Globally, 140 billion metric tons of biomass is generated every year from agriculture waste of which can be converted to useful energy such as biofuel [2]. Numerous agricultural residues and wastes are generated in Nigeria which are poorly utilized and badly managed, since most of these wastes are left to decompose or burned in the field resulting in environmental pollution and degradation contributing to the negative impacts of climate change [3]. In Nigeria, a large quantity of rice husks and cormcobs are produced annually, and these residues are left to rot away or burned like other agricultural wastes. These residues could however, be used to generate energy for domestic and industrial cottage applications [4]. The decreasing availability of fuel wood coupled with the ever-rising prices of kerosene and cooking gas in Nigeria has drawn attention on the need to consider alternative sources of energy for domestic and industrial use in the country. Such energy sources should be renewable and accessible to everyone especially those in rural and vulnerable settlements.

Briquetting is a process of binding together pulverized materials (such as sawdust, groundnut shell coconut husk, male inflorescence of oil palm, rice husk, maize cob, bamboo and other combustible materials) into a solid block compressed material under pressure, often with the aid of binder such as cassava starch. The use of briquette can reduce the demand for fuel wood and therefore reduce the over-exploitation of forest resources by rural dwellers. Briquette production have the potential of meeting the additional energy demands of urban and industrial sectors, thereby making a significant contribution to the economic

advancement of countries especially the developing countries. Furthermore, briquettes have advantages over fuel wood in terms of greater heat intensity, clean production, convenience, and relatively smaller space requirement for storage [5]. The amount of energy required for various purposes keep on increasing due to the increase in demand. Majority of these waste materials constitutes a form of nuisance to the environment which are left to decompose, or they are burned in the field resulting in environmental pollution and degradation and thereby contributing to unclean environment. Hence, the utilization of coconut husk and male inflorescence of oil palm which are known to be waste should therefore be encouraged which in turn helps to produce briquette from waste materials.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted at the Federal University of Agriculture, Abeokuta. The University is located at Alabata road in the north Eastern part of Abeokuta in Odeda Local Government of Ogun state Nigeria at latitude 3 to 20° E to 30° W. The region enjoys an average rainfall of 1300 mm and annual temperature of about 31.8°C with peaks in June and dry season of two or three month.

2.2 Materials Collection and Preparation

Coconut husk and Male Inflorescence Oil Palm tree were used for this study. Cassava Starch was used as binder while weight top screw presser was used to form briquette. The Male Inflorescence Oil Palm tree was collected from Oil Palm tree along Federal University of Agriculture Abeokuta (FUNAAB) gate via Alabata and the coconut husk was collected at FUNAAB neighborhood in Ogun State environs.

Collected male inflorescence was sundried and shredded into powdery form as well as the coconut husk to reduce the moisture content and grinded into powder. The grinded samples were then sieved with 2 mm mesh sizes to obtain uniformity in their particle sizes. The particles obtained from the mixture of male inflorescence and coconut husk were weighed into varied proportions (20:25:30:50:60) and were produced with the aid of a locally fabricated mould. Cassava starch (40:50:60) which is the binding agent was mixed to each sample in a different proportion and moulded using screw presser to form the briquette. After the production, the briquette was weighed to determine their weight.

2.3 Place of Study

The laboratory test was carried out at the Forestry Research Institute of Nigeria (FRIN) Ibadan, Nigeria where the proximate analysis and heating values were determined.

2.4 Proximate Analysis

Proximate analysis was carried out to determine the constituents of the briquettes which includes the following:

- Ash content
- Percentage fixed carbon
- Percentage Volatile matter

2.4.1 Determination of percentage ash content

2 g of oven dried briquette sample was placed in the furnace at temperature of 550°C for 4hours and weigh after cooling.

$$\text{Percentage Ash content} = \frac{D}{B} \times 100 \quad [1]$$

Where

D = Weight of Ash
B= Weight of oven dried sample

2.4.2 Determination of percentage volatile matter

The volatile matter was determined by placing 2 g of pulverized briquette sample in a crucible oven to obtain constant weight which was kept in the furnace at temperature of 550°C for 10mintes and then brought out to be cooled in the desiccators and weighed to determine percentage volatile matter.

$$\text{Percentage Volatile matter} = \frac{D-C}{B} \times 100 \quad [2]$$

Where

B = weight of dried samples
D = weight of Ash
C = weight of sample after 10 minutes in the furnace at 600°C.

2.4.3 Determination of percentage fixed carbon

The percentage fixed carbon was calculated by subtracting the sum of percentage volatile matters and percentage ash content from 100%.

$$\text{Percentage Fixed Carbon} = 100 - (\%V + \%A) \quad [3]$$

Where

%V= percentage volatile matter
%A= percentage Ash Content

2.4.4 Determination of heating value/energy

The calorific value was determined using Parr Oxygen bomb calorimeter in accordance with CEN/TS 14918 Standard Method [6].

Heating value was calculated using this formula:

$$\text{HV} = 2.326(147.6C + 144V) \text{ kJ/kg} \quad [4]$$

C=Percentage Fixed carbon
V=Percentage Volatile Matter

2.5 Data Analysis

The experiment was laid down using the Randomized Complete Block Design (RCBD). The data were subjected to one-way Analysis of Variance (ANOVA) at 0.05 probability level. Where significant differences were encountered, the means were separated using Duncan Multiple Range Test (DMRT). Descriptive statistics that includes mean and standard error of estimates was also used to describe the data. All analysis was done using the SPSS software Version 20.0 (IBM, Chicago).

3. RESULTS AND DISCUSSION

3.1 Percentage Ash Content

Knowledge of the ash content tells the extent of clogging up of the burning medium. High ash content decreases the burning rate and reduces the heating value of fuel. The result of

percentage ash content from this study shows that briquette produced with 20% coconut husk, 20% male inflorescence of oil palm and 60% starch has the least ash content of 6.5%. The result of the percentage ash content observed in this study was lesser when compared to previous work as reported by Husain et al. [7] with an ash content of 6% obtained on briquetting of palm fibre and shell from the processing of palm nuts to palm oil. Briquettes with lower ash content are considered better fuel because it produces less smoke. According to Cohen and Marega [8], biomass residues normally have much lower ash content (except for rice husk with 20% ash), but their ashes have a higher percentage of alkaline minerals, especially potash. High ash content results into dust emissions which lead to air pollution and affects the combustion volume and efficiency. Chaney [9] revealed that the higher the fuel's ash content, the lower its calorific value since it influences the burning rate due to minimization of the heat transfer to fuel's interior parts and diffusion of oxygen to the briquette surface during char combustion. The ash content of different types of biomass with lower ash content will not show any slagging behaviour of the biomass. Obi et al. [10] also noted that low ash content offers higher heating value for briquettes but high ash content results into dust emissions which lead to air pollution and affects the combustion volume and efficiency. Generally, the greater the ash content the greater the slagging behaviour, but this does not mean that biomass with lower ash content will not show any slagging. The mineral composition of ash and

their percentage combined determine the slagging behaviour. Hence, briquettes made from 20% coconut husk, 20% male inflorescence of oil palm and 60% will be more suitable for domestic uses like cooking.

3.2 Percentage Volatile Matter

The result of percentage volatile matter shows that briquette produced with 20% coconut husk, 20% male inflorescence of oil palm and 60% starch has the highest volatile matter (74.6%) but lower to that of briquette which is in accordance with previous studies [11] and were higher than those obtained by other researchers in their works [12,13,14] which explained that the materials and binders which were selected are better for briquetting. The percentage volatile matter of the briquettes was higher than normal value of 20% as reported Ivavov and Kuznetsov [15]. High volatile matter in the results of this research is an indication of easy ignition, fast burning and proportionate increase in flame length. Moore and Johnson [16] noted that biomass generally contains high volatile matter of around 70% and 80% with low char content.

3.3 Percentage Fixed Carbon

The fixed carbon of the briquette is a percentage of carbon (solid fuel) available for char combustion after volatile matter is distilled off or lost to the atmosphere. Therefore, fixed carbon gives a rough estimate of the heating value of fuel and acts as the main heat generator during burning [12]. The result in Table 1 is

Table 1. Anova showing comparison in the ash content, volatile matter, fixed carbon and heating value among samples

| Samples | Ash content (%) | Volatile matter (%) | Fixed carbon (%) | Heating value (MJ/kg) |
|--------------------|---------------------------|------------------------------|-------------------------------|------------------------------|
| CH/S (50:50) | 7.0000±0.200 ^b | 63.3333±5.1316 ^a | 21.4333±2.45832 ^{ac} | 24.4133±1.37 ^a |
| CH/S (60:40) | 6.7333±0.665 ^a | 59.6667±3.0550 ^a | 20.3100±0.90570 ^{ab} | 21.6467±1.70 ^a |
| CH/S (40:60) | 6.8333±0.208 ^a | 64.0900±1.2674 ^a | 21.2633±1.87538 ^c | 22.7167±1.24 ^a |
| MI/S (50:50) | 8.7367±0.439 ^d | 62.9833±4.6111 ^a | 19.7900±1.72357 ^a | 23.9100±1.59 ^a |
| MI/S (60:40) | 9.3467±0.566 ^d | 58.9933±0.9308 ^a | 18.8133±0.85582 ^a | 23.6933±2.72 ^a |
| MI/S (40:60) | 9.8333±0.763 ^d | 59.3500±3.4967 ^a | 19.1333±0.28431 ^a | 21.7400±1.01 ^a |
| CH/MI/S (25:25:50) | 8.2667±1.418 ^c | 61.6667±2.5166 ^a | 21.3033±2.20123 ^c | 24.2500±0.85 ^a |
| CH/MI/S (30:30:40) | 7.1833±1.284 ^b | 70.5000±1.32288 ^b | 23.0000±0.86603 ^{bc} | 25.3333±1.04083 ^a |
| CH/MI/S (20:20:60) | 6.5000±0.500 ^a | 74.6667±4.64579 ^b | 24.0000±1.00000 ^c | 25.5667±2.10079 ^a |

Values represent mean ±standard deviation.

Values of ash content, volatile matter and fixed carbon with different superscripts are significantly different at 1% ($p < 0.01$) level. Values of heating value represent mean ±standard deviation. Values with the same superscript are not significantly different at 5% ($p < 0.05$) level.

CH = Coconut Husk, MI = Male Inflorescence of Oil Palm, ST = Starch

further illustrated on a bar chart in Fig. 2. Table 1 shows the result of comparison in the number of fixed carbon observed among the 9 different samples. The result shows that the average number of fixed carbon in the 9 samples ranged from 18.8133% to 24.0000% with the highest number of fixed carbon recorded in sample CH/MI/S (20:20:60) while the least number of fixed carbon was recorded in sample MI/S (60:40). The result shows further that the average number of fixed carbon varied significantly among the 9 different samples at 1% ($p < 0.01$) level (Table 1). The result in Table 1 is further illustrated on a bar chart in Fig. 3. This result further shows that briquette produced with 60% male inflorescence and 40% starch has the least percentage fixed carbon of 6.5% hence, has a better performance for briquette production. The result of this study contradicts the work done in the past [17] which stated that the higher the fixed carbon content of a fuel, the greater the calorific value, the smaller the volatile matter, the lower the ash and moisture content and the better the quality of the fuel.

3.4 Heating Value

The result of the analysis of variance (ANOVA) showing comparison in heating value among the 9 different samples was reported (Table 1). The result shows that the average heating value for the 9 samples ranged from 21.6467 to 25.5667 MJ/kg with the highest heating value observed in sample CH/MI/S (20:20:60) while the least heating value was recorded in sample CH/S (60:40). However, the result shows that the average heating value did not vary significantly among the 9 different samples at 5% ($p > 0.05$) level (Table 1). The result in Table 1 is further illustrated on a bar chart in Fig. 4. The result of heating value obtained from this research was higher than the briquette produced from groundnut shell using cassava peel as binder (33.70MJ/kg) reported in previous studies [17]. The result was also higher than the durian peel conducted in previous work [18] with the heating value of 20.265 MJ/Kg and also lower than that of 33.09 MJ/kg reported in literatures [11,13], this may be as a result of the treatments composition

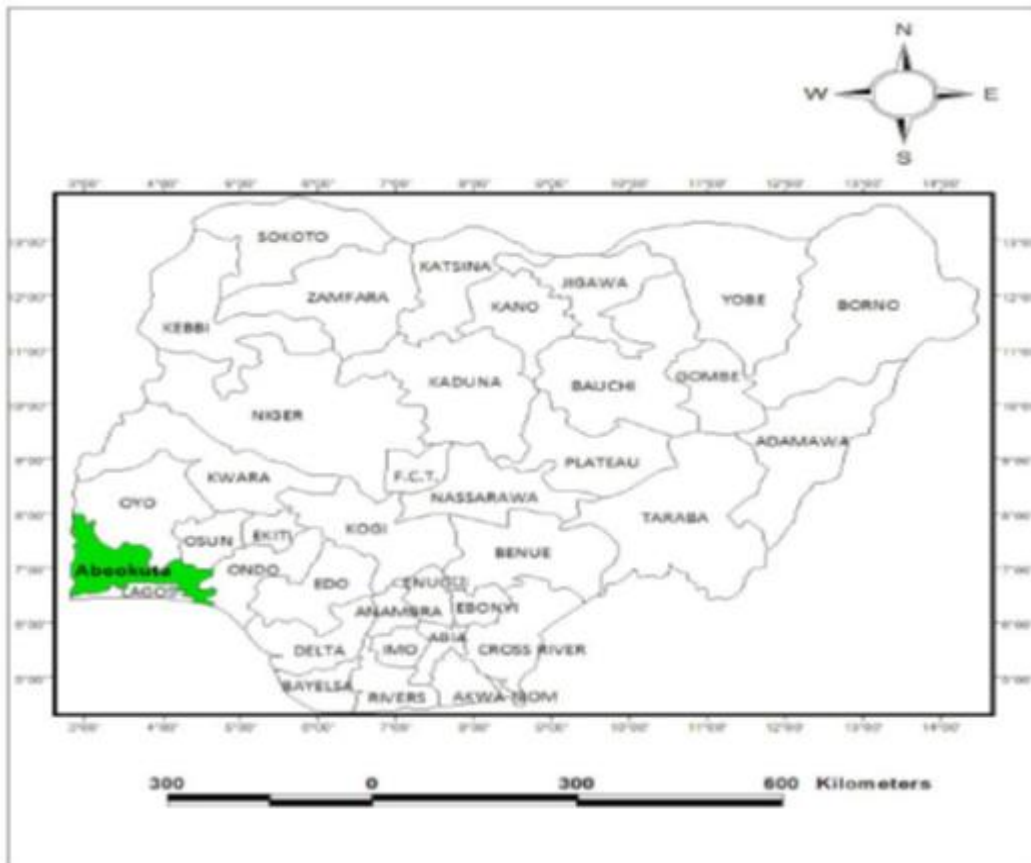


Image. 1. Map of the study location

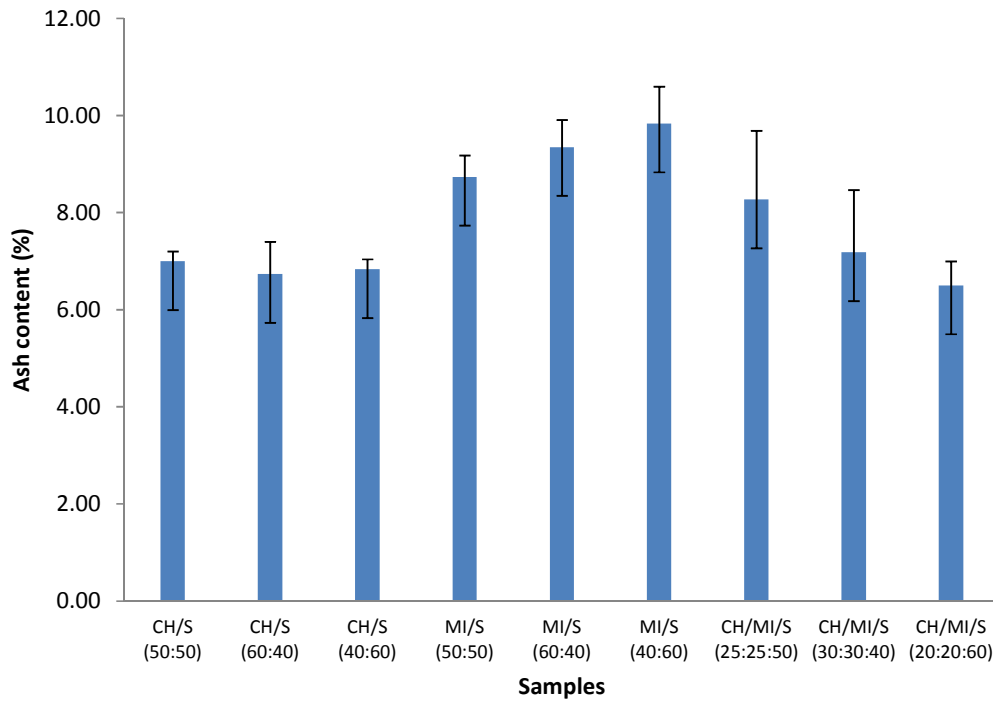


Fig. 1. Bar chart showing variations in the ash content of the samples

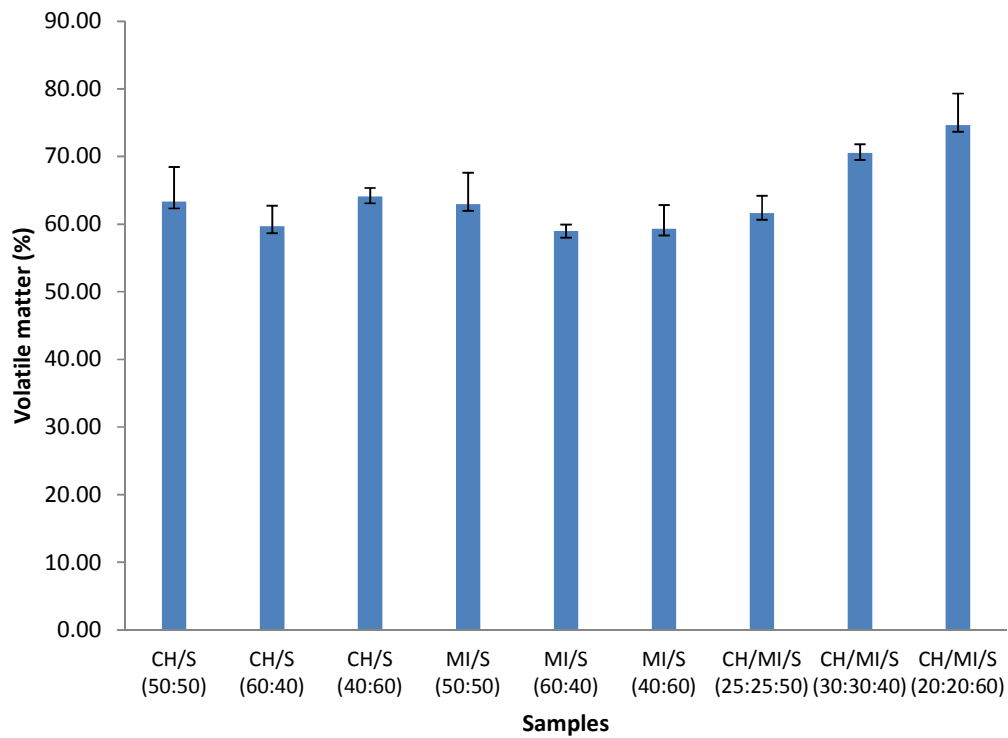


Fig. 2. Bar chart showing variations in the volatile matter of the samples

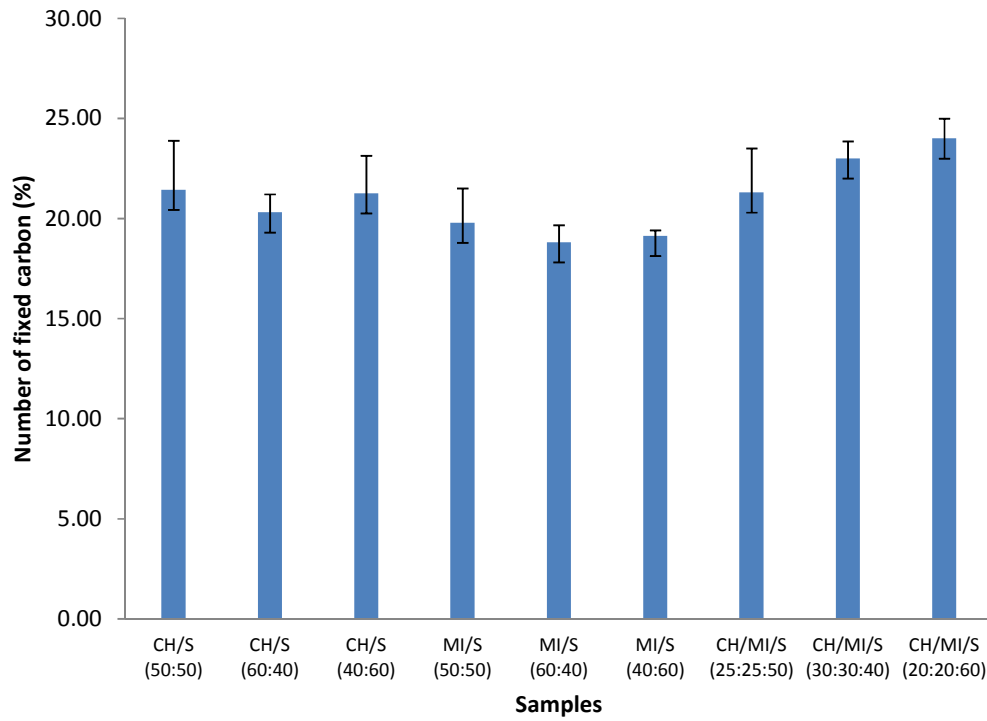


Fig. 3. Bar chart showing variations in the fixed carbon of the samples

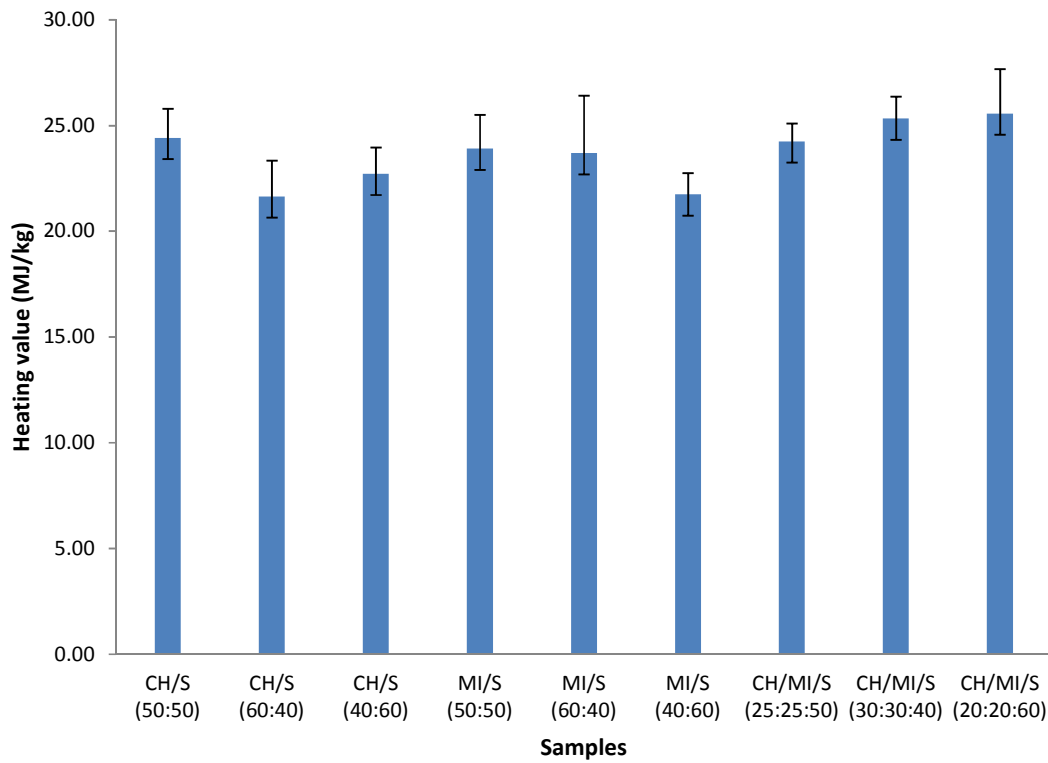


Fig. 4. Bar chart showing variations in the heating value of the samples

Table 2. Analysis of variance result for ash content, volatile matter, fixed carbon and heating value

| | | Sum of squares | df | Mean square | F | Sig. |
|-----------------|----------------|----------------|----|-------------|-------|------|
| Ash | Between Groups | 37.195 | 8 | 4.649 | 7.555 | .000 |
| | Within Groups | 11.077 | 18 | .615 | | |
| | Total | 48.272 | 26 | | | |
| Volatile Matter | Between Groups | 685.089 | 8 | 85.636 | 7.609 | .000 |
| | Within Groups | 202.591 | 18 | 11.255 | | |
| | Total | 887.679 | 26 | | | |
| Fixed Carbon | Between Groups | 70.665 | 8 | 8.833 | 3.829 | .009 |
| | Within Groups | 41.520 | 18 | 2.307 | | |
| | Total | 112.185 | 26 | | | |
| Heating Value | Between Groups | 48.097 | 8 | 6.012 | 2.295 | .068 |
| | Within Groups | 47.160 | 18 | 2.620 | | |
| | Total | 95.257 | 26 | | | |

or different treatment used in the study. The result of this study also compares well with that of the calorific value of charcoal and sawdust briquette observed in previous studies [19].

4. CONCLUSION

Waste in terms of coconut husk and male inflorescence which are generated in large quantities and disposed indiscriminately can be utilized to produce solid fuel known as briquettes. Briquettes are very efficient since the quality of solid fuel depends on factors such as providing enough heat at a time necessary, easy ignition without danger, less smoke generation and less harmful gases to the environment. From the result of this research, it was evident that briquettes can be satisfactorily produced from coconut husk and male inflorescence of oil palm. Therefore, the use of briquette should be encouraged especially in developing countries to reduce pressure on fuel wood for energy generation.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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