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Proximate analysis of some common charcoal in Southwestern Nigeria

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ABSTRACT

Common charcoals from different wood species were collected, identified and prepared for analysis. Proximate analyses were carried out. The study aimed to characterize the identified charcoal and suggest the best charcoal that will give the minimal pollution effect. The result showed that the moisture content of the charcoal ranges between 3.26 and 8.40 wt% with an arithmetic mean of 5.36 ±1.50 wt%, the volatile content ranges between 3.05 and 13.62 wt% with an arithmetic mean of 7.20 ±3.55 wt%, the fixed carbon ranges between 76.83 and 90.57 wt% with an arithmetic mean of 83.54 ±4.60 wt%, and the ash content ranges between 3.09 and 5.18 wt% with an arithmetic mean of 3.87 ±0.70 wt%. The heating value of charcoal of different wood species were determined using Bomb calorimeter. Afzelia bipindensis has the highest ash content while Hevea brasiliensis has the lowest ash content. The heating value ranges 31.82–39.42 kJ/kg with a mean of 35.375 ±2.673 kJ/kg. This shows that *Burkea africana* could be best for use as a cooking fuel for households and restaurants because it has the best fuel property in terms of moisture content.

1. Introduction

The consumption of charcoal has greatly increased and people are not considering the effect of using charcoal on their overall health. Therefore, there is a need to find the best way of reducing such effect. There is a need to opt for an alternative energy that does not have its origin in fossil fuel [1]. observed the effects of using fossil fuel. The reason for this is to address concerns about fossil fuels, like its high carbon dioxide emissions, and also adverse effect on global warming. Therefore, researchers have developed interest in alternative energy in many countries. As a way of promote and support the researcher to find solution to alternative energy from renewable source [2,3].

In Africa and South America, the consumption of charcoal is gradually increasing than the consumption of firewood and its use is becoming a greater part of the world's total energy. However, the use of charcoal changes from region to region in tropical America. In Brazil, for example charcoal is majorly used in manufacturing industry while in Central America it is mainly used in the food industry and also as a household energy source. In sub-Saharan Africa charcoal is mostly as domestic energy source, majorly for urban dwellers [4].

In Africa, charcoal production has provided employment for millions of people [5–7] and it is the major source of fuel for heating and cooking many urban centres [5]. The demand for charcoal has increased due to the increase in population and movement of people from rural to urban areas, [5,6,8,9]. In urban areas of Sub-Saharan African countries about 50% use charcoal, 25% use firewood whereas in the rural areas, (where most of the household energy demand is used for cooking) more than 90% households use firewood for cooking and less than 5% use charcoal [5]. Charcoal is servicing the ecosystem by contributing to the welfare of the rural population, e.g providing services such as (charcoal, grass, fruits, firewood, water), regulating services (purification of water, control of erosion) and cultural services (holy places, recreation) [10–14]. No other works have extensively discussed the best charcoal that will give minimal effect in Southwest, Nigeria, hence this study.

Using biofuels provides significant benefits to the environment. During plant growth, biomass absorbs CO_2 and releases it during combustion. Hence, biomass promotes the recycling atmospheric CO_2 and does not contribute to the greenhouse effect. The quantity of carbon dioxide released during combustion is the same as that taken up from the atmosphere during combustion [15]. No other works have extensively discussed the best charcoal [16] that will give minimal effect in Southwest, Nigeria, hence this study. Because the use of charcoal in Nigeria especially in the southwest region is greatly increasing. Therefore, this study was especially focused on chemical properties of biomass

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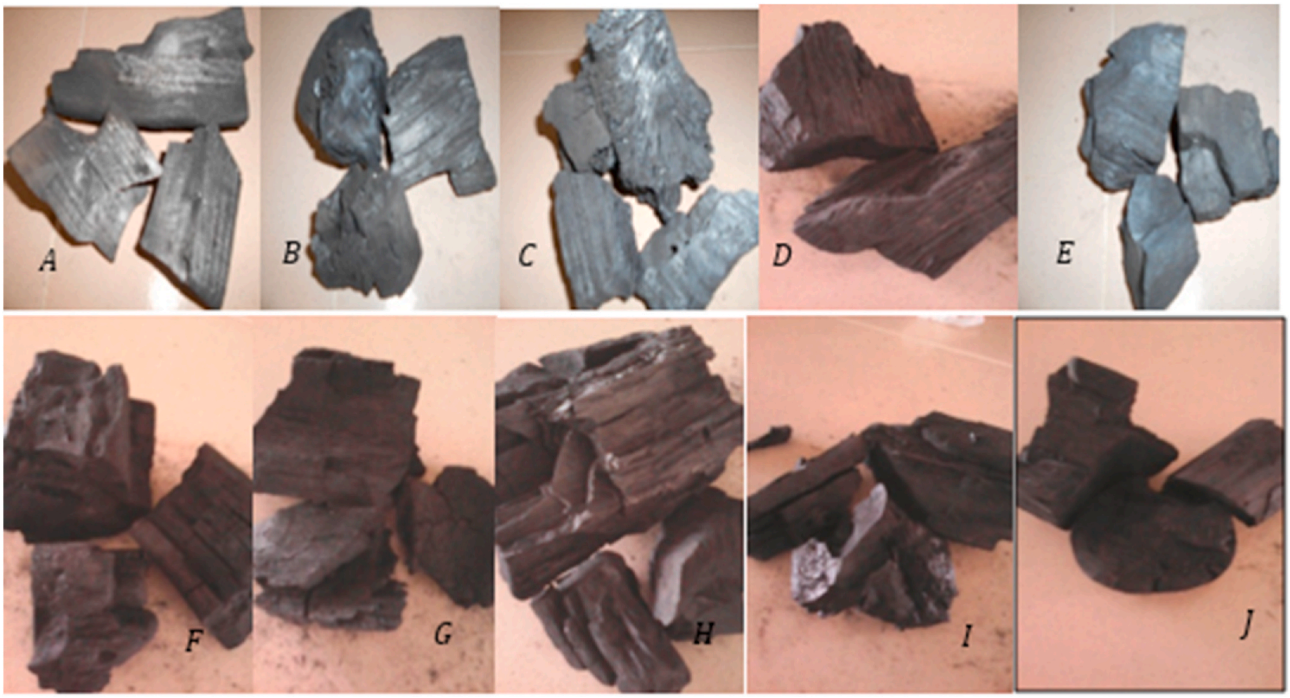

Fig. 1. Charcoal samples.

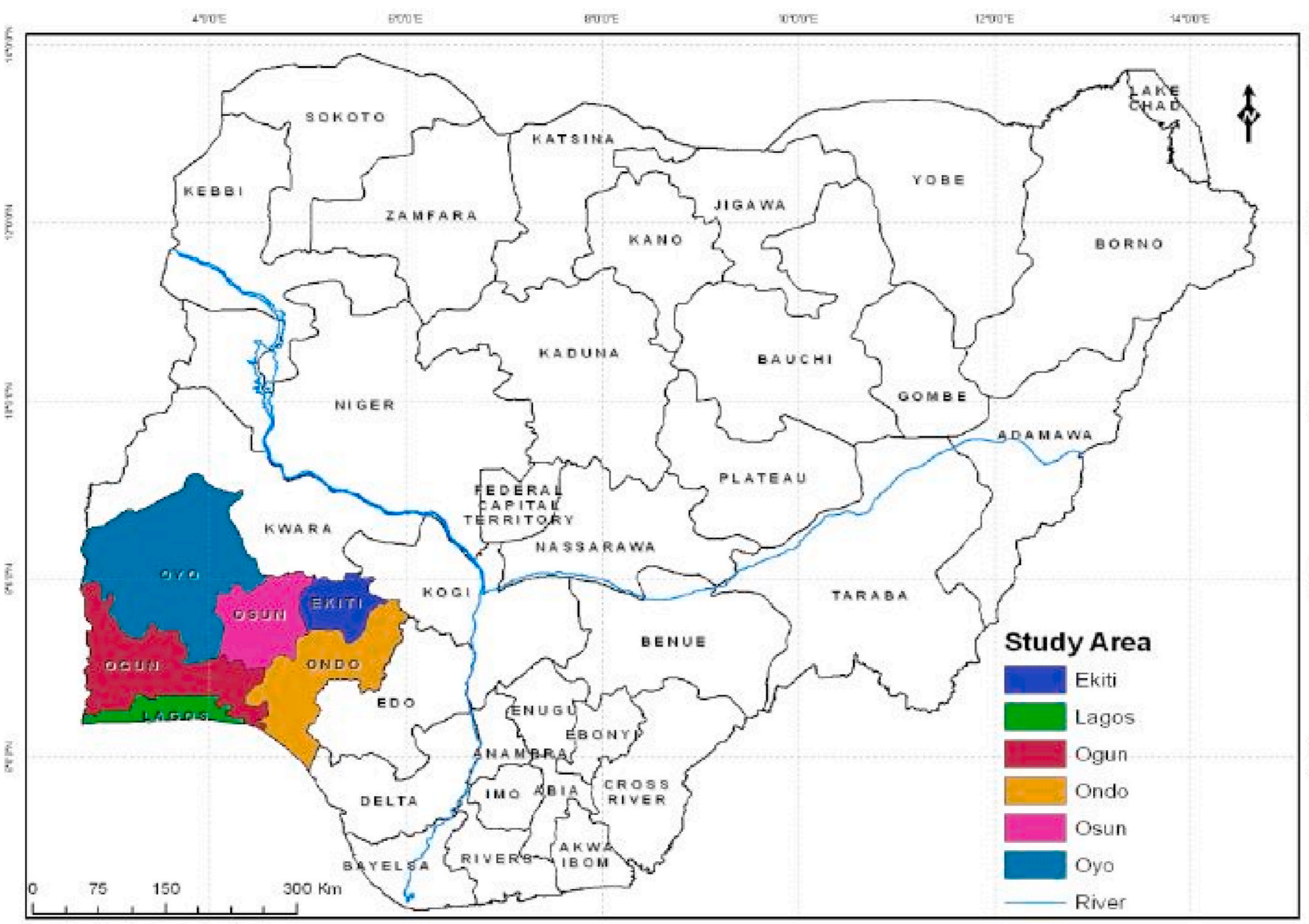

Fig. 2. Map of Nigeria showing the study areas [19].

fuel which includes heating value, carbon (C) and hydrogen (H), nitrogen (N) and sulphur (S) content and the charcoal was identified. The results from the proximate analysis and heating value was discussed. It also sought correlate the heating value with the results of the proximate analysis.

2. Materials and methods

Ten charcoal samples were collected in southwestern Nigeria. The samples were identified and prepared for analysis. The charcoal species includes: (A) *Anogeissus leiocarpa* (Ayin), (B) *Afzelia bipindensis* (Ayan), (C) *Vitellaria paradoxum* (Emi), (D) *Burkea Africana* (Asapa), (E) *Albizia zygia* (Ayunre), (F) *Hevea brasiliensis* (Rubber), (G) *Milicia excelsa* (Iroko), (H) *Terminalia avicennioides* (Idi), (I) *Funtumia elastica* (Ire), (J) *Milletia thonningii* (Ito). The samples are shown in Fig. 1.

2.1. Study area

The study area is south-western Nigeria and these includes of Lagos, Ogun, Oyo, Osun, Ondo and Ekiti states. It is also called the south west geographical zone of Nigeria and the map is shown in Fig. 2. The longitude of the area lies $2°31^1$ and $6°00^1$ East and Latitude $6°21^1$ and $8° 37^1$ N [17] with about 77,818 km^2 land area and the population is about 32.5 million in 2006 [18]. South western, Nigeria is bounded in the North by Kogi and Kwara states, in the South by the Gulf of Guinea, in the East by Delta and Edo states and in the West by Benin Republic. The study area had a forest cover of 842,499 ha and 85 constituted forest reserves.

2.2. Proximate analysis

Proximate analysis typically involves the determination of moisture content, volatile matter, fixed carbon, total carbon and ash content.

2.2.1. Determination of moisture content

The weight of silica crucible was measured using the digital weighing balance and recorded w_1 (g), the spatula was used to fetch 1.00 g of pulverized solid waste samples inside the crucible. The content kept inside the silica crucible and the crucible was measured and recorded as w_2 (g). It was then heated in a muffle furnace at a temperature of 105 °C for 1 h. The crucible is taken out, cooled in a desiccator and weighed. The percentage of moisture content is given by:

$$\%\ Moisture\ content = \frac{loss\ in\ weight}{weight\ of\ sample\ taken} \times 100 \tag{2.1}$$

2.2.2. Determination of volatile matter

A unit weight of moisture free pulverized sample in the silica crucible was weighed on the digital weighing balance as w_3 (g). The sample was further heated in a crucible fitted with cover in a muffle furnace at a temperature of 950 °C for 7 min. It was cooled in the desiccator and weighed on the digital weighing balance as w_4 (g). The percentage volatile matter in the combustible components of the sample was determined.

2.2.3. Determination of ash content

This is the resultant weight of the residue after combustion a known mass of grounded charcoal in an open crucible (i.e. in presence of air) at 750 °C in a muffle furnace till a constant weight is achieved). The crucible was weighed on the digital weighing balance and recorded as w_1 (g). Spatula was used to fetch 1.00 g of solid charcoal sample into the silica crucible. It was measured and recorded as w_6 (g). The sample in the open crucible was thereafter burnt (in the presence of air) at a temperature of 750 °C in a muffle furnace till a constant weight is achieved.

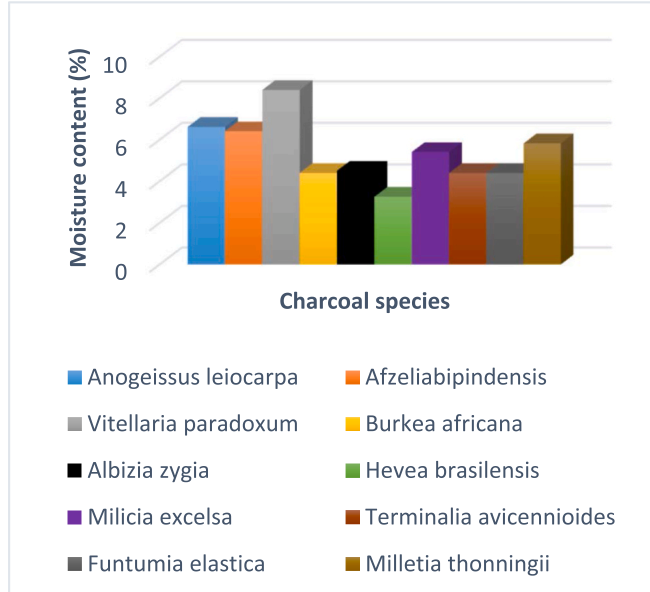

Fig. 3. Percentage moisture content for different charcoal species.

2.2.4. Determination of fixed carbon

The percentage fixed carbon was determined directly by deducting the total sum of moisture, volatile matter and ash percentage from 100.

$$\%Fixed\ Carbon = 100 - (\text{moisture content} + \text{volatile matter content} + \text{ash content})\% \tag{2.2}$$

2.2.5. Total carbon

The percentage total carbon of the sample was determined directly by adding the volatile matter and the fixed carbon together.

$$\%Total\ Carbon = \text{Volatile matter} + Fixed\ Carbon \tag{2.3}$$

2.3. Heating value

Charcoal samples were ground and 0.5 g of it was weighed using digital weighing balance. The corresponding mass was entered through the PC keyboard of the calorimeter. The sample was placed in the weighed crucible and inserted into the crucible holder. Be sure that the firing cotton touches the samples. The lid assembly inserted into the vessel body and the cap down was screwed until it touches the top of the lid. The vessel was placed into the vessel holder under the filling station and filled with oxygen to 3000 kPa.The vessel was inserted into the measuring chamber and then the lid was closed. Switch on the START button to determine the heating value.

3. Results and discussion

From this results, *Vitellaria paradoxum* (emi) has the highest moisture content (8.40%), while *Hevea brasilensis* (rubber) has the lowest moisture content (3.26%). *Burkea africana* (asapa), *Terminalia avicennioides* (idi) and *Funtumia elastica* (ire) have the same moisture content (4.40%) as presented in Fig. 3. The charcoal species with higher moisture content are the best for biochemical conversion processes while those with lower moisture content are the best for thermal conversion processes [20]. When moisture content is high, it means that the heat of combustion is partly used to remove water from the biofuel while when it is not high, it means that all the heat is used for the actual purpose. Low moisture content permits a very high flame temperature (with the best temperature gradient and allowing complete combustion) and shorter time in the chamber for combustion processes [21].

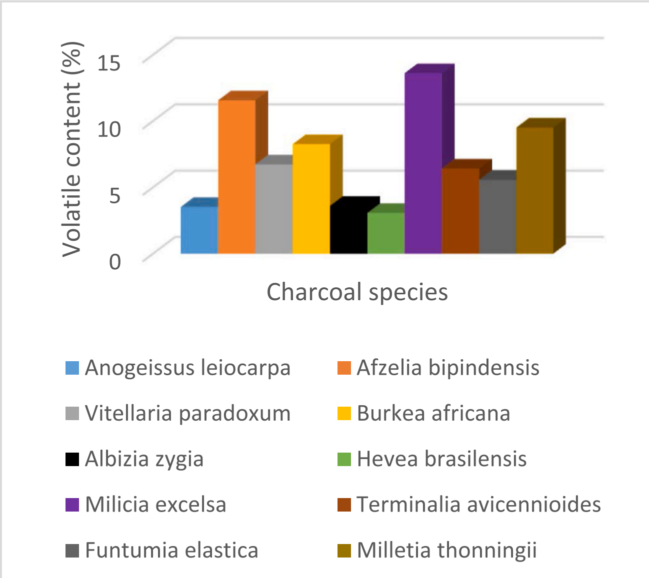

Fig. 4. Percentage volatile matter content for different charcoal species.

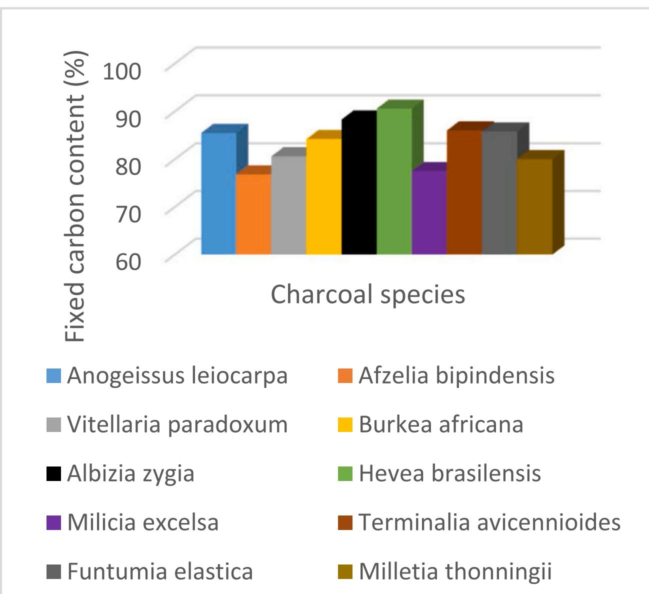

Fig. 5. Percentage fixed carbon content for different charcoal species.

Volatile matter significantly affects the thermal decomposition and burning of biomass fuels ([22,23]). The percentage volatile matter has the highest value in *Milicia excelsa* (iroko) 13.62% and lowest value in *Hevea brasilensis* (rubber) 3.08% as shown in Fig. 4. This indicates that *Milicia excelsa* (Iroko) will have the highest durability when stored. Low volatility charcoals were *Hevea brasilensis* (rubber), *Albizia zygia* (ayunre), *Anogeissus leiocarpa* (ayin) while high volatility charcoals were *Milicia excelsa* (iroko), *Afzelia bipindensis* (ayan), *Milletia thonningii* (ito), *Burkea africana* (asapa). Low volatility in charcoal may be connected with low level of extractives and high level of lignin in wood. The fixed carbon of these charcoal species ranged from 76.83% for Ayan to 90.57% for Rubber as shown in Fig. 5. *Hevea brasilensis* (rubber) with the highest followed by *Albizia zygia* (ayunre), *Terminalia avicennioides* (idi), *Funtumia elastica* (ire) while *Afzelia bipindensis* (ayan) with the lowest fixed carbon followed by *Milicia excelsa* (iroko), *Milletia thonningii* (ito), *Vitellaria paradoxum* (emi) and *Burkea Africana* (asapa).

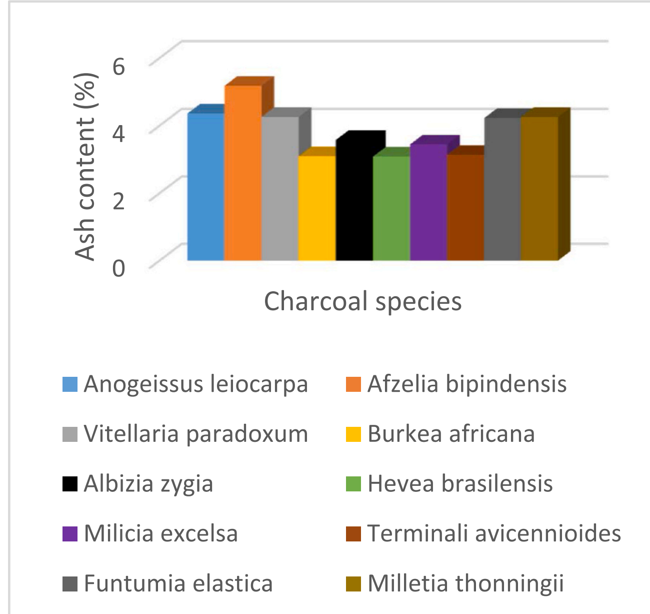

Fig. 6. Percentage ash content for different charcoal species.

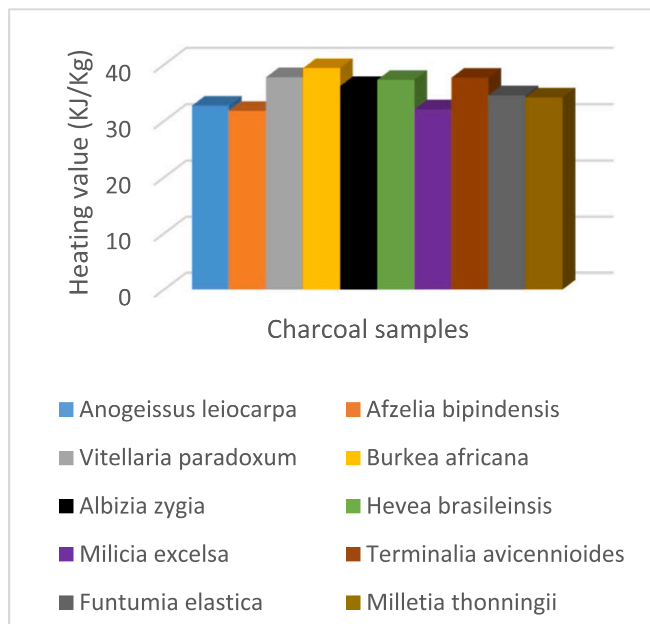

Fig. 7. Percentage calorific value for different charcoal species.

The ash content form these charcoal species ranges from 3.09% for rubber to 5.18% for *Afzelia bipindensis* (Ayan) as shown in Fig. 6. *Afzelia bipindensis* (Ayan) with the highest ash content indicates that it has high mineral matter. The ash content is generally low; *Anogeissus leiocarpa* (ayin), *Afzelia bipindensis* (ayan), *Vitellaria paradoxum* (emi), *Milletia thonningii* (ito), and *Funtumia elastica* (ire) is greater than 4% while the ash content of *Burkea africana* (asapa), *Milicia excelsa* (iroko), *Terminalia avicennioides* (idi), *Albizia zygia* (ayunre) and *Hevea brasilensis* (rubber) is less than 4%. Therefore, if charcoal species from *Anogeissus leiocarpa* (ayin), *Afzelia bipindensis* (ayan), *Vitellaria paradoxum* (emi), *Funtumia elastica* (ire) and *Milletia thonningii* (ito) are used as a source of fuel, slagging would not occur but if charcoal species from *Burkea africana* (asapa), *Milicia excelsa* (iroko), *Terminalia avicennioides* (idi), *Albizia zygia* (ayunre) and *Hevea brasilensis* (rubber) are used as a source of fuel,

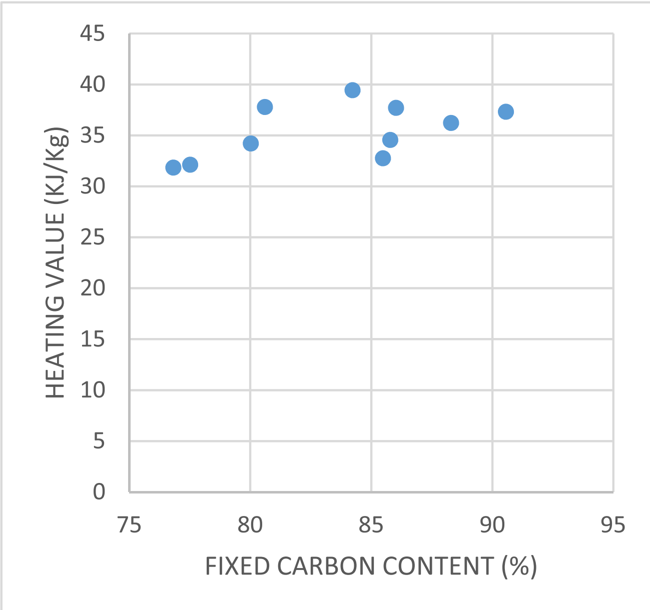

Fig. 8. Correlation between heating value and fixed carbon content.

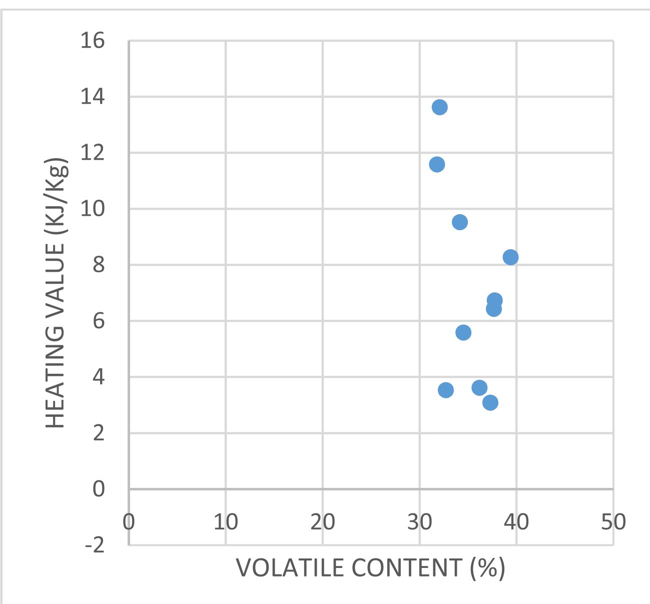

Fig. 9. Correlation between heating value and volatile matter content.

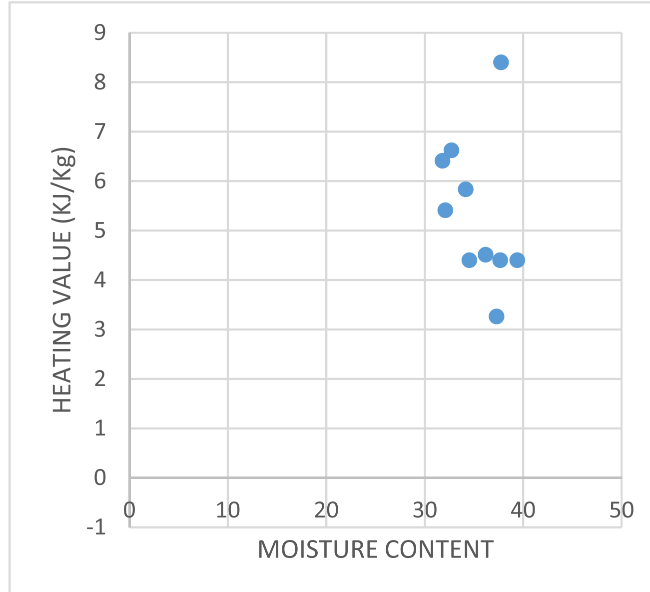

Fig. 10. Correlation between heating value and moisture content.

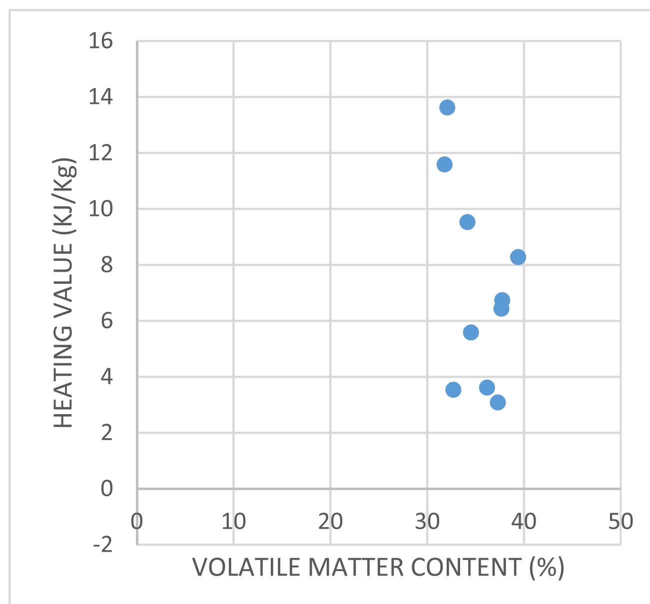

Fig. 11. Correlation between heating value and volatile matter content.

slagging may not occur. Also, high ash content may result in high level of operating discomfort when use in residential areas. Higher percentage ash in *Anogeissus leiocarpa (*ayin), *Afzelia bipindensis* (ayan), *Vitellaria paradoxum* (emi), *Milletia thonningii* (ito), and *Funtumia elastica* (ire) may be due to high concentration of magnesium and potassium. Good rank charcoal has ash content between 0.5 and 5% [2]. It was reported that [24] that an uncertain relationship exists between calorific value and ash content of biomass (the importance of ash content to calorific value is not yet known).

The calorific value is used to determine the energy content of biomass. It is usually affected by ash content, moisture content and elemental composition of charcoal. The highest energy content is (39.41*KJ/Kg*) for *Burkea Africana,* followed by *Vitellaria paradoxum* (37.77*KJ/Kg*), *Terminalia avicennioides* (37.69*KJ/Kg*), *Hevea brasilensis* (37.31*KJ /Kg*), *Albizia zygia* (36.20*KJ /Kg*), *Funtumia elastica* (34.54*KJ/ Kg*), *Milletia thonningii* (34.18*KJ /Kg*), *Anogeissus leiocarpa* (32.73*KJ /Kg*), *Milicia excelsa* (32.10*KJ /Kg*), *Afzelia bipindensis* (31.82*KJ/Kg*) has shown in Fig. 7 Is the lowest. The highest ash content of *Afzelia bipindensis* is responsible for its lowest heating value. Figs. 8–12 shows that heating value exhibit fairly positive correlation with fixed carbon content (r = 0.54), negative correlation with volatile matter (r = −0.44), ash content (r = −0.65), moisture content (r = −0.29), weak positive correlation with carbon content (r = 0.47). This means that the higher the heating value the higher the fixed carbon content and the higher the heating value the lower the moisture, volatile, and ash content while on the other hand, the higher the heating value the higher the fixed carbon content.

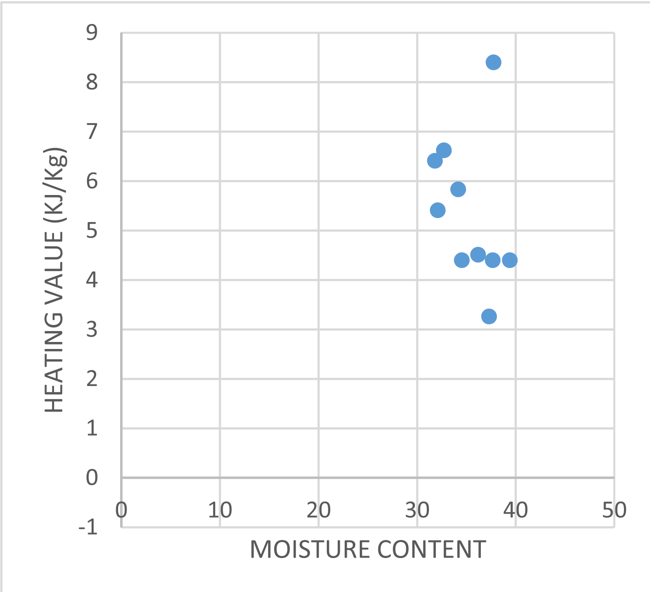

Fig. 12. Correlation between heating value and moisture content.

4. Conclusion

This study was to characterize some common charcoal in south-western Nigeria. All charcoal samples were compared. The results revealed that *Hevea brasilensis* had the lowest moisture content of 3.26%, the highest fixed carbon of 90.57%, the lowest ash content of 3.09% and lowest volatile matter of 3.08%. *Afzelia bipindensis* had the highest ash content of 5.18%, the lowest fixed carbon of 76.83% and the lowest heating value of 31.82%. *Burkea Africana* had the highest heating value of 39.41%. Therefore, charcoal from *Burkea africana* could be best for use as a cooking fuel for households and restaurants based on this study because it has the best fuel property.

Credit author's statement

Oke Michael Abidemi: Writing – original draft preparation. Sonibare Jacob Ademola: Review, Editing and supervision, Onakpohor Anthony: Conceptualization. Akeredolu Funsho Alaba: Supervision. Odunlami Abosede Oyelami: Methodology. Elehinafe Francis Boluwaji: Editing.

Declaration of competing interest

There is no financial or personal relationship with other people that can influence the state of the work.

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