Evaluation of Proximate Properties and Heating Values of Wood and Bark Content of Five Common Firewoods in Yobe State, Nigeria

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Abstract

The study determined the influence of proximate properties and heating values of wood and bark contents of five different firewood species. The experiment was conducted with a view to resolve the indiscriminate use of firewood with and without bark contents for energy values by the people in the study area. Majority of the people depend on firewood as a source of energy for domestic and commercial uses. Five different firewood species samples were obtained at three different locations at Damaturu, Yobe State. Each of the tree species was cut at 25 cm long and replicated three times. Therefore a total of fifteen firewood species samples were used for the study. The wood and bark were independently subjected to proximate analysis using ASTM standards. Meanwhile, the statistical test was performed using ANOVA and Duncan's multiple range test (DMRT). The results of the study reveal that the high volatile matter was obtained in a wood portion of Sclerocarya birrea with 83.03% while a lower value of 75.19 % was found in Combretum lamprocarpum while its bark portion was found to be 65.69 % in Combretum lamprocarpum and lowest value of 44.69% was found in Piliostigma reticulatum. The variation in ash contents of wood portions ranges from 0.16% in Acacia sieberana to 0.46 % in Sclerocarya birrea. Conversely, the bark portion ranges from 5.36% in Tamaridus indica to 6.15 % in Acacia sieberana. The fixed carbon content of wood ranges from 16.51% in Sclerocarya birrea to 26.26% in Tamarindus indica, while 29.76 to 47.49% was recorded from bark portions. The heating value of the wood portion was found to be 33.48 Jkg-1 in Sclerocarya birrea to 33.65 Jkg-1 in A. sieberana. On the other hand the bark portion of 31.27 Jkg-1 was obtained in P. reticulatum and 32.22 Jkg-1was recorded from C. lamprocarpum. It is concluded that the bark content of wood insignificantly affects the proximate properties and heating value of firewood species.

Introduction

The main source of energy for domestic and commercial cooking, heating, and steaming in most of Nigeria, especially Northern Nigeria is usually firewood. However, in the northeast region, the vegetation cover is Sudan/Sahel savanna, where trees are scarce and scattered (Dadile and Sotannde, 2020). The fourth-largest source of energy in the world after coal, oil, and natural gas, which together account for 10% of all energy use, is wood. (Ladanai and Vinterback, 2009). In addition, the over-dependence on firewood in northern Nigeria is alarming due to the environmental changes in the region, such as desertification, flooding, drought, and above all, global warming. This mainly occurs due to the over-exploitation of forest resources coupled with the release of fossil fuel resources which damage the ozone layer (Bergerson and Keith, 2006). Meanwhile, the region's indiscriminate tree felling, rising population and the unreliability of alternative energy sources (such as kerosene, liquefied petroleum gas (LPG), and electric appliances) for domestic and commercial cooking and heating contributes to the indiscriminate felling of tree species in the region.

The belief of people in the study area on preference to use a wood portion (xylem) and firewood with bark portion where there was no valid inference, and this necessitate the study to find out a valid inference on the quality of firewood. This could be achieved through charactering their fuel properties (Gordobil, *et al.*, 2016; Patel and Gamil, 2012). The fuel properties of firewood species vary from one species to another, while the fuel characteristics of the same species' wood and bark vary depending on how much of each is present (Dadile *et al*., 2020). Additionally, it's critical to consider the fuel properties (such as ash content, Volatile content, Fixed carbon content, and Heating value) when assessing the suitability of a firewood species as a fuel source for cooking and heating. This information is typically obtained through standard test methods, proximate analysis, and heating value. is If this information is known, low-quality firewood species will be discouraged from being used for domestic and commercial cooking, protecting the, environment by minimizing atmospheric gas emissions and meeting or exceeding strict public health and air-quality standards (Kumar *et al*., 2010). Such information is usually obtained by standard test methods, proximate analysis, and heating value. In this context, the heating value is one of the most important parameters for determining the energy value of wood and bark content. The energy value of different type of firewood during combustion is greatly influenced by the concentration of volatile matter and essential oils (Perez *et al*., 2006). Numerous researchers have also commented on the characteristics of various tree species, including their wood, bark and leaves (Fuwape and Akindele, 1997; Senelwa and Sim, 1999; Klasnja *et al*., 2002; Rothpfeffer and Karltun, 2007). Therefore, study aims to determine the heating value of wood and bark contents of firewood species.

Materials And Techniques

2.1 Materials

The resources consulted for the study were obtained in an open forest area 10 kilometers away from Damaturu, Yobe State of Nigeria. Five firewood species samples mentioned in their biological and Hausa name includes *Piliostigma reticulatum* (Kalgo), *Tamarindus indica* (Tsamiya), *Acacia sieberana* (Farar Kaya), *Sclerocarya birrea* (Lulu-Danya), and *Combretum lamprocarpum* (Kattakara) were obtained at three different locations. The firewood species, on the other hand, were each replicated three times and cut at a length of 25cm above the diameter at breast height (DBH), yielding a total of fifteen samples. Each billet (a sample cut at 25 cm length) was wrapped in black nylon to prevent moisture loss and conveyed to the laboratory. The samples were debarked and reduced to a small size with the use of an axe in the lab. Afterwards, the samples were subjected to proximate analysis using ASTM standard tests.

2.2 Methodology

2.2.1 Determination of Proximate Properties

2.2.1.1 Moisture Content

The moisture content of the wood chips was determined by weighing one gram of the freshly produced wood chips into an empty, known-weight platinum crucible allowed us to calculate the wood chips' moisture content. To a steady weight, the oven dried at 105 ± 2^0c. Following this, the samples were taken out of the oven and allowed to cool in a desiccator before their ultimate weight was gauged and noted. Utilizing the equation below, the oven dry moisture content was determined:

$$MC = \frac{W_o - W_1}{W_1} \times 100\% \quad (1)$$

Where, MC represents the Moisture content in percent,

W_0 represents the initial weight of the freshly prepared wood fraction,

W_1 represents the ultimate weight of the wood fraction following drying to a constant weight at 105±2^{o}c

2.2.1.2 Vaporized substances

One gram of the oven-dried samples was placed in a platinum crucible with a known weight. The crucible was then heated in a furnace at 500^{0}c for 10 minutes, cooled to room temperature in a desiccator, and then reweighed as the final weight and substituted in the formula below to determine the volatile matter. .

$$VS = \frac{X - Y}{X} \times 100\ \% \quad (2)$$

Where:

VS represents the percentage of vaporized Substances,

X represents the weight of oven-dried wood fraction (g) and

Y represents the weight (g) of the wood fraction after 10 min in the furnace 500^{o}C.

2.2.1.3 Determination of Ash Content

One gram of each sample was weighed and poured into a platinum crucible of known weight. The crucible was then heated in a furnace at a temperature of 600^{0}C for 30 minutes before being allowed to cool to room temperature in a desiccator to determine the amount of ash present. The calculation below was used to calculate and weigh the ash in the crucible. (Sluiter *et al.*, 2008).

$$\text{AC}\ (\%) = \frac{M}{Mo} \times 100\ \% \quad (3)$$

Where, AC represents the ash content,

M represents the mass of the ash and M_o represents the mass of the oven-dried sample

2.2.1.4 Fixed Carbon

The solid combustible residue left over after the wood particle has been heated and the volatile component has been expelled is the fixed carbon. By removing the percentages of moisture, volatile matter, and ash from a sample, the fixed carbon content can be calculated (encyclopedia Brittanica, 2018)

$$FC = 100 - \%MC - \%AC - \%VM \quad (4)$$

Where: *FC* stands for percentage fixed carbon,

VM for volatile matter, and

AC for ash content in the wood fraction.

2.2.1.5 Heating Value

Using the Gouthal formula, the heating value was determined in accordance with Bailey and Blankehorn (1982).

$$HV = 2.326\,(147.6FC + 144VM) \quad (5)$$

Where, *HV* denotes heating value in MJ·kg^{-1},

FC is the fraction of fixed carbon, and

VM denotes volatile matter

Results And Discussion

Five distinct types of wood species were analyzed. The species were named in their Hausa and biological names as (Tsamiya (*Tamarindus indica*), Lulu- danya (*Schlerocarya birrea*), Kattaqara (*Combretum Lamprocarpum*), Kalgo (*Piliostigma reticulatum*) and Farar kaya (*Acacia sieberana*) obtained in the forest area at ten (10) kilometers away from Damaturu.

The findings of the close examination of firewood species in this investigation is presented in figures. The higher value of percentage moisture content was obtained from the bark content, while the least moisture content was observed in the wood portion. This indicates that the wood portion will give the bark content's maximum fuel calorific value among the bark content considered in this study. The variation in the amount of moisture content among firewood species in this study significantly influences the combustion rates of the tree species. Various studies have demonstrated the influence of MC on the combustion properties of firewood materials (Ojelel *et al.*, 2015; Nosek *et al.*, 2016; Álvarez-alvarez *et al.*, 2018) and concluded that moisture has a negative effect on fuel value. Therefore, firewood species with low MC are always preferred because of their high energy content per unit volume and slow burning rate.

According to Wakili *et al.* (2009), wood with high moisture content produces low energy output. However, high MC in the bark content of the firewood signifies that the bark portion possessed a larger number and size of capillaries than the wood portion, resulting in lower energy values in the bark content than in the wood portion (Ojelel *et al.*, 2015).

The vaporized substances (volatile matter) of each piece of firewood was relatively high. The volatile matter varies from 44.96% *Acacia sieberan* to 83.03% *Schlerocarya birrea,* with *Schlerocarya birrea* having the highest value in the wood portion and *Acacia sieberana* the least (Fig. 2). However, the highest volatile matter was obtained from the bark content of 65.69% in *Combretum Lamprocarpum* while the least was found to be 44.69% in *Piliostigma reticulatum.* The values obtained from the wood portion were higher than that of the bark content. When a biomass material's vaporized substance (volatile matter) is high, it means that most of it will volatilized and burn as gas during combustion. . Therefore wood portion has the highest volatile matter compared to bark content of firewood species in this work (Fig. 2). Additionally, the values of volatile matter in both wood and bark portions were found to be a relatively high. This is similar to the report by Deka *et al*. (2014) that higher values of volatile matter obtained in some indigenous tree species in the wood and bark portions, but slightly less than the range of between 74.7 to 87.1% in certain wood (Telmo and Lousada, 2011; Demirbas, 2007). Moreover, greater volatility of matter observed in the wood portion compared to bark contents signifies that, the wood part contains a higher amount of functional groups and less aromatic structures are found in wood portions than in the bark contents. The highest percentage of ash content in the wood portion of all the firewood species in this study varies from 5.36% for *Tamarindus indica* to 7.83% for *Piliostigma reticulatum* (Fig. 3). Conversely, the least ash content was found in the bark content of the firewood species which varies from 0.16% in *Acacia sieberana* to 0.46% in *Schlerocarya birrea* (Fig. 3). The present of significant levels of mineral substance in the firewood species is indicated by the high ash content among the wood and bark. . This is in line with the reports of Demirbas and Arin, 2002; Shanavas and Kumar, 2003; Deka *et al.*, 2014; Nosek *et al.*, (2016).

Percentage fixed carbon for these firewood species of the bark content varied from 29.76% in *Combzretum lamprocarpum* to 47. 49% in *Piliostigma reticulatum* while, low fixed carbon was found in the wood portion with 16.51% in *Sclerocarya birrea* to 26.26% in *Tamarindus indica* (Fig. 4). The high fixed carbon content was found in the wood portion while the least value was obtained from the bark content. This indicates that high fixed carbon content will require a long combustion time. The values discovered in this study were comparable to those discovered by Deka *et al*. (2014) in some native tree species but greater than the range of 13.50 to 23.02% discovered by Álvarez-Álvarez *et al*. (2018). The high volatile matter content of the samples used in this investigation is reflected in their high fixed carbon content, which according to Senelwa and Sims (1999), is a sign that the majority of the firewood material is burned mostly in a gaseous condition.

Meanwhile, during the burning of a fuel, fixed carbon, which provides a rough estimate of the heating value of the fuel, is the primary heat generator. Also, the greater, fixed carbon of firewood species the more chance of having a higher heating value. However, higher heating values were obtained in the wood portion of the firewood species utilized in this research which varied from 33.59 J/kg in *Combretum Lamprocarpum* to 33.65 J/kg in *Acacia sieberana* (Fig. 5). While the least heating values were obtained in the bark content which ranged from 31.27 to 33.22 J/kg in *Piliostigma reticulatum* and *Combretum Lamprocarpum* respectively (Fig. 5). This implies that wood portion has high heating value than the bark content of firewood species. This indicates that the use of firewood species with their respective bark content will increase the heating value of the wood portion to 45-50%, in that the bark content produces considerable heating value. Similarly, Nasser and Aref, (2014), reported 18.00 to 20.45 J/kg heating values for some *Acacia* species and 19.26 to 20.64 J/kg north India uses the wood and bark of various native tree species as fuel woods and barks of some indigenous tree species in north-east India for fuel by Deka et al., (2014) and Chavan *et al*. (2016) reported high heating values in some wood species but higher than 13.78 to 22.22 J/kg reported by Demirbas and Arin (2002) for some ash free and extractive free biomass.

Conclusion

The inherent fuel characteristic quality of the wood and bark portion significantly influences the proximate properties and energy values of the firewood species used in this study. The least moisture content observed in the wood portion is an indication that, wood portion gives highest calorific value than bark content. Similarly, the high volatile matter was also observed in the wood portion, which indicates that the firewood species will have high carbon content and as such, will have high heating value. Meanwhile, high ash content was observed in the bark content, which indicates that mineral composition is much higher in the bark content than in the wood portion of the firewood species. , As a result, it can be concluded that the removal of bark content of firewood species for use in cooking, heating, and steaming has negative impact on the heating value of the firewood species. However, i a significant amount of heating value was observed in the bark content, which can be added to increase the heating value of wood portion, resulting in a gross heating value greater than60 J/kg rather than removing bark content.

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Figures

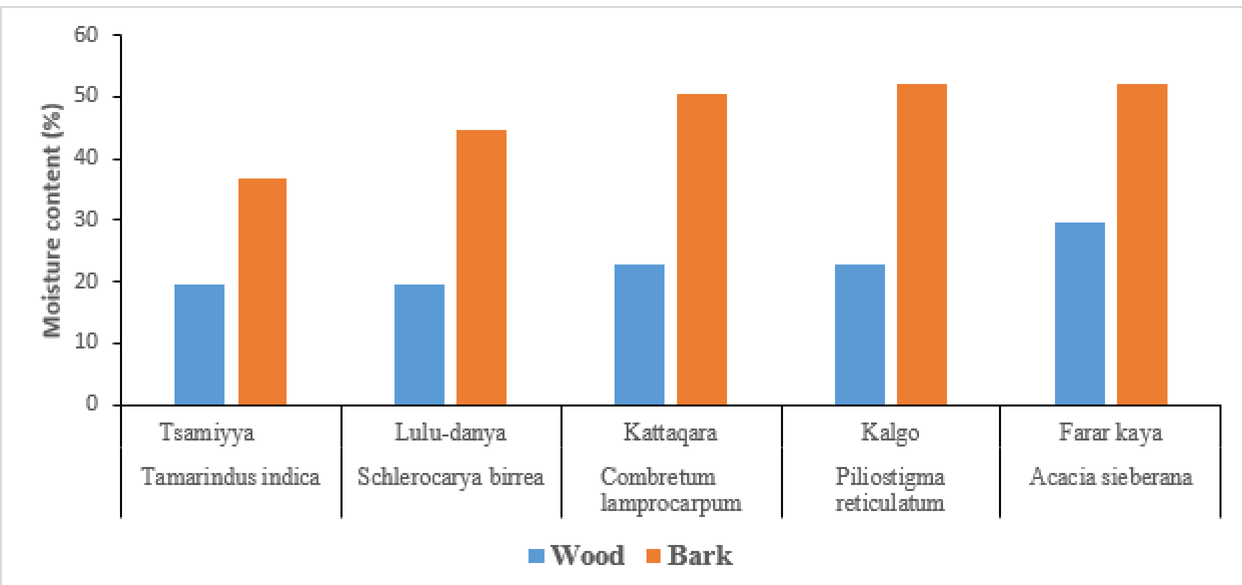

Figure 1

Percentage moisture content in wood and bark portion of selected tree species

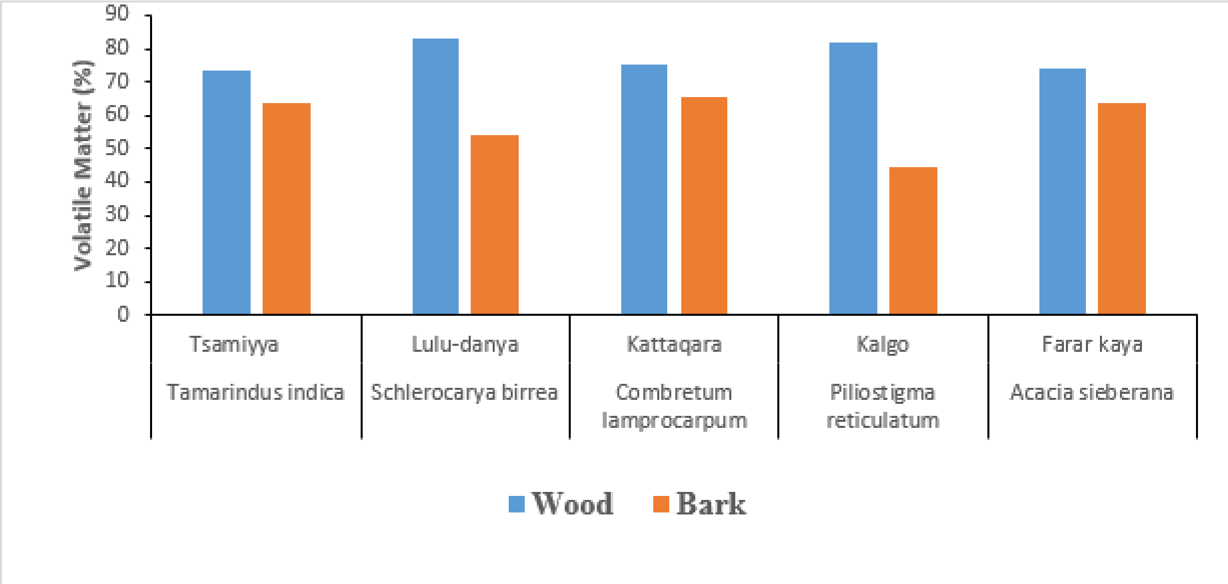

Figure 2

Percentage moisture content in wood and bark portion of selected tree species

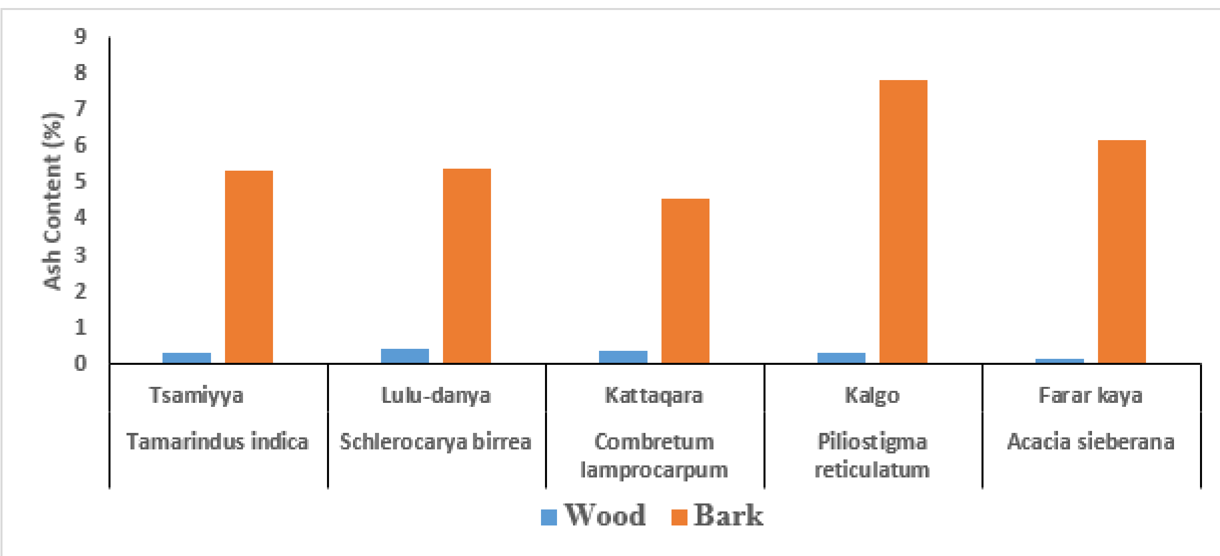

Figure 3

Percentage ash content in wood and bark of selected tree species

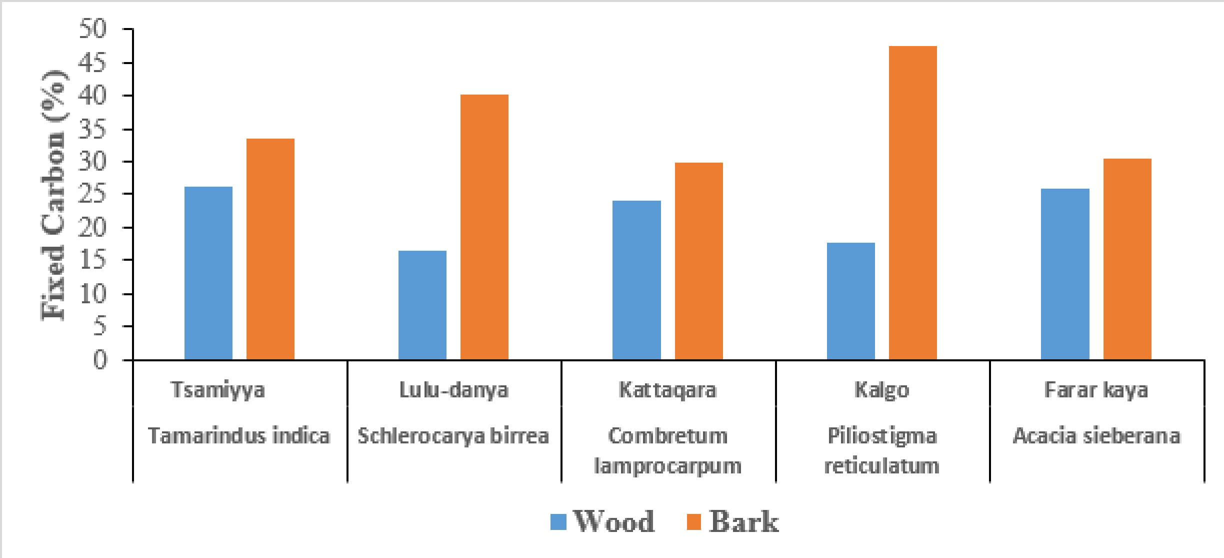

Figure 4

The percentage of wood's fixed carbon of selected tree species

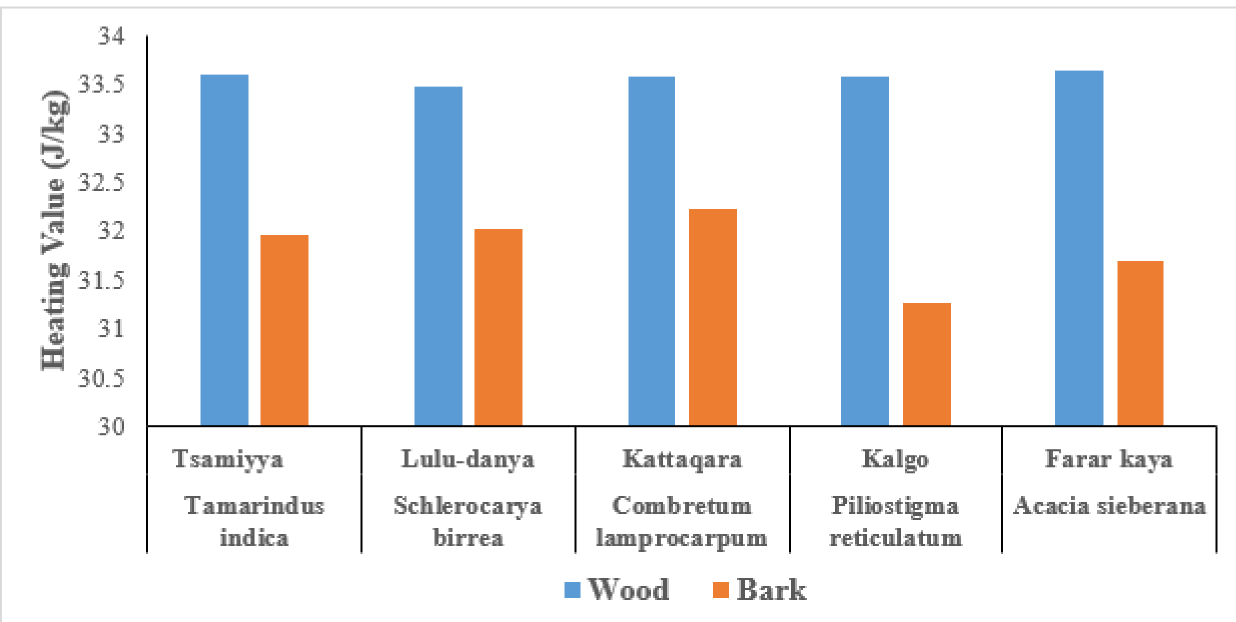

Figure 5

The Influence of Heating Values for the Wood and Bark Portion of Some Selected Tree Species