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ENERGY PROPERTIES AND FUEL POTENTIALS OF SELECTED INDIGENOUSLY PROCESSED BIO-RESOURCES USED AS SOURCES OF SUSTAINABLE FUEL IN NORTH CENTRAL NIGERIA

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ABSTRACT

The stems of two matured shrubby plants identified as Vernonia colorata (wild bitterleaf) and Hibiscus canabinus (kenaf) were studied for their energy properties and fuel potentials. The two samples were collected, dried and pulverized. The volatile combustible compounds believed to be responsible for the bright flame produced on combustion were determined. Also determined in the two samples were the physical energy properties which include; fixed carbon, ash content, ultimate values, calorific value, moisture contents (MC). These parameters provide a rough estimate of the heating value of a fuel biomass and acts as the main heat generators during combustion. They were low in the samples when compared with charcoal used for heating purposes, indicating they may not be used for such purposes. Meanwhile, the gases emitted by these plant materials on combustion were detected using multigas detector (Altair 5x Multigas). The results obtained indicate the concentrations of CO, SO_2 and H_2S gases emitted from the processed bioresources after subjecting them to combustion, averaged 680.25mg/m^3, 3.13mg/m^3 and 4.40mg/m^3 respectively, which indicated they were within acceptable standard limits, suggesting using them is environmentally friendly. The technology employed in making the plants provide more sustainable fuel for the light normally boost the bio resources to expose the volatile contents of the substances provide the needed bright flame.

Keyboard: Energy, fuel, bio-resources, sustainable fuel

INTRODUCTION

The looming global energy crisis has prompted the search for alternatively energy sources globally in recent times. This is attributed to daily energy demand from various works of life like schools, homes, business areas and industries. It is forecasted that global energy demand could rise to 50% by the year 2025, with major part of the increase in demand coming from emerging economies (Agbro and Ogie, 2010). Part of the approaches needed to solve the energy crisis is to explore and establish empirical evidences to indigenous skills and techniques that were used in the ancient time as sources of energy in some tropical African communities. For instance, common with the *Mushere*, *Chakfem*, *Mchip*, *Mupun*, *Angas*, *Mwaghavul* communities and many other indigenous communities in Central Nigeria is the use of locally processed stems of shrubby plants like *Hibiscus cannabinus* (kenaf) *and Vernonia colorata* (wild bitter leaf) to provide bright flames needed for illumination in the dark during the night. From the processed stem of these plants which these communities called '*giyam'* they are able to get sustainable burning flames that provides bright light in dark places within their households. This skill and technology is fading away without exploring their potential which might eventually be the answer to the widely acclaimed global need for sustainable alternative energy source.

The indigenous process technology used by these communities involves harvesting the matured plants, drying and dipping in muddy water for 4-5weeks, during which it is believed to have undergone some catalytic and microbial transformations (Figure 1).

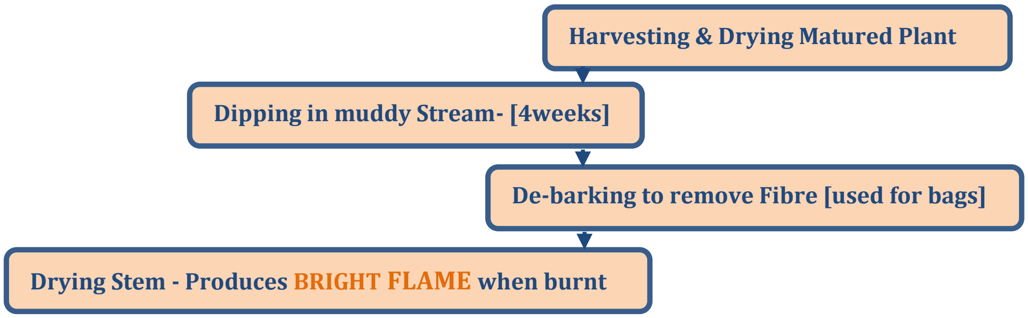

Figure 1: Flow Chart for traditional processing of the biomasses.

The processed stem has a very good combustion property as it is observed to burn continuously for some time with sustainable bright flame which acts as source of light in the dark with little smoke to pollute the environment. Like every other flammable material, it is expected that there should be some volatile components in the processed plant stem products which are responsible for the sustainable burning quality, unlike the unprocessed plant stem which does not produce such a sustainable bright flame. This is in line with an earlier work (Chaula *et al.*, 2014), which confirmed that, those biomasses that contain a high content of volatile components, burn with a thick and bright flame. This aim of the research was to investigate the energy potentials and fuel properties of plants widely used as sources of sustainable burning bright flame by indigenous communities in North Central zone of Nigeria.

MATERIALS AND METHODS

Plant collection and preparation

The *H. canabinus* and *V. colorata* samples were harvested between November and December when they were fully matured and sun-dried. After drying, the samples were soaked in muddy water for at least 5 weeks, debarked and sun-dried the second time. The dried stems were crushed and ground with pestle and mortar. The pulverized samples were then sieved to obtain a particle size of 0.50 - 1.00mm.

Moisture Content (%)

3.0g of the sample was weighed and placed in a crucible, then kept in the oven at 105^{o}C for one hour. The sample was removed and placed in a desiccator to cool, after which it was weighed and until uniform successive weight were obtained on repeating the process. The loss in weight after drying was expressed as percentage moisture content.

Moisture Content = $M_n = (W_w - W_d) / W_w \times 100\%$

Where: M_n = Moisture content (%) of material, W_w = Wet weight of the sample, W_d = Weight of the sample after drying.

Ash content (%)

The percentage ash content of the sample was determined by heating 5.0g of each the samples in a muffle furnace maintained at 600^{o}C for three hours. Thereafter, it was cooled and weighed. This represents the ash content of the samples. The percentage ash content was calculated as follows.

$$\text{Ash Content (\%)} = \frac{\boldsymbol{M}ash}{\boldsymbol{M}over\ dry} x\ 100\%$$

Where:
M_{ash} is the mass of ash and,
$M_{over\ dry}$ is the mass of over dried sample

Volatile Matter (%)

The volatile matter (%) of the biomass material was determined by weighing 3.0g of each of the sample kept in a muffle furnace at 500^{o}C for 10 minutes and weighed after cooling in desiccators. The crucible was then weighed and the loss in weight accounts for the volatile content of the charcoal.

The percentage volatile matter was then calculated as follows:

$$\text{Volatile Matter (\%)} = \frac{\boldsymbol{A} - \boldsymbol{B}}{\boldsymbol{A}} x\ 100\%$$

Where **A** is the weight of the oven-dried sample and **B** is the weight of the sample after 10 minutes in the muffle furnace at 500^{o}C

Fixed Carbon (%)
This was obtained from the expression below adopted by Efomah and Gbabo (2015).
Fixed carbon (%) = 100 – (moisture content % + Ash content % + Volatile matter %)

Ultimate Analysis
These were done on the samples based on methods adapted (Akowuah *et al.,* 2012*;* Saheed *et al*., 2015). The value of the Volatile Matter (Vm) obtained was used to evaluate important chemical constituents of the biomass materials namely carbon, hydrogen, Nitrogen using the formulas below;

$\% C = 0.97C + 0.7 (V_m – 0.1_A) – m (0.6 – 0.01m)$

$\% H = 0.036C + 0.086 (V_m – 0.1A) – 0.0035_a^2 (1 – 0.02m)$

$\% N_2 = 2.10 – 0.20V_m$

Flue Gases Detection:
A calibrated multi gas detector (Air Master) was used. It is a hand-held instrument equipped to perform automatic analysis of air sample through the use of output signal. Flue gas (sample) from the combustion of the charcoal entered the analyzer for the identification and quantification of the gaseous pollutant and other gases such as; CO, H_2S, SO_2, O_2 and combustible were detected from the samples.

Determination of the Heat of Combustion (Calorific Value)
The calorific value was determined by weighing 1.0g of the samples, from which 1.0 ml of water was added to the oxygen bomb calorimeter and oxygen gas introduced. This was then placed in a bucket in the calorimeter which normally contains 1.0 litre of water and left to burn. The temperature was checked at interval of 1 to 5minutes until complete combustion was obtained. Calorific value was obtained using the expression below:

$$Hg = \frac{Final\ Temp - Initial\ Temp)\ (Heat\ Capacity\ of\ the\ Bomb\ Calorimeter)}{Wieght\ of\ Sample}$$

RESULTS
The proximate analysis of *H. canabinus* and *V. colorata* processed stems are presented in Figure 2. The volatile matter contents of the samples were; 83.35% and 77.18% for the *H. canabinus* and *V. colorata*, respectively. The relatively high volatile matter in both plants justify why they are widely used as sources of sustainable flame. The ash content for both *H. canabinus (*8.60%) *and V. colorata* (4.65%) gives the amount of the inorganic matter left out after complete combustion. While the fixed carbon contents were; 8.69% for *V colorata* and 0.23% for *H. canabinus*, which was low in both samples.

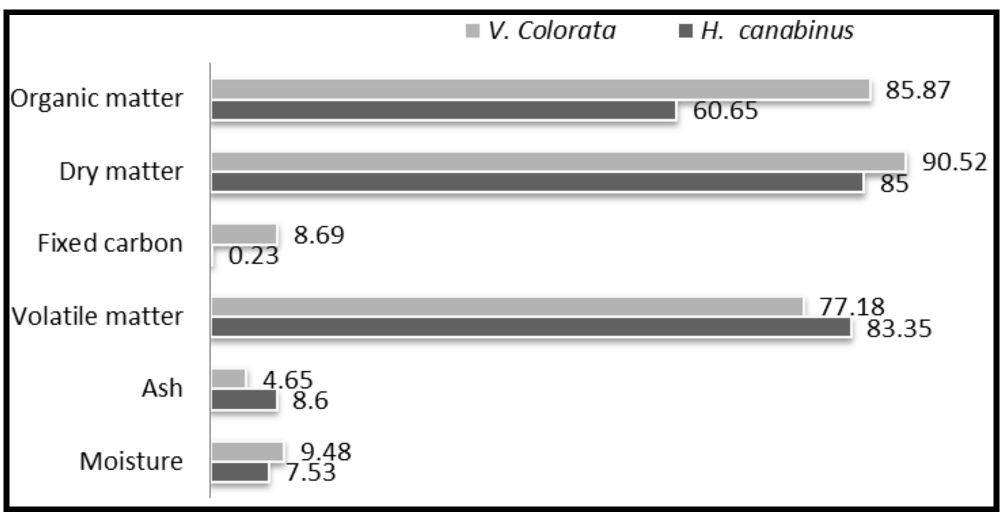

Figure 2: Proximate analysis of *H. canabinus* and *V. colorata (%)*

Figure 3 presents the ultimate analysis of the *V colorata* and *H. canabinus* stem obtained from proximate analysis. Ultimate analysis involves the estimation of important chemical elements that makes up the biomass, namely; carbon (C), hydrogen (H), oxygen (O), nitrogen (N) and sulphur (S), they are responsible for the heat generating potential of the biomasses. The results for *V. colorata is* 57.34%, 6.56%, 35.50%, 0.56% and 0.04% for C, H, O, N and S respectively. While that of *H. canabinus* is C : 45.54%, H : 4.02%, O :31.32%, N : 0.20% and S : 0.01%. The results obtained is within the limits of a similar work reported by Chaney (2010), which indicates the composition of the principal constituents as carbon ranging from 30 to 60% , oxygen 30-40%, hydrogen between 5-6%, while nitrogen and sulphur normally makes up less than 1% of dry matter biomass. The average oxygen to carbon ratio (O/C), hydrogen to carbon ratio (H/C) and carbon to nitrogen ratio (CN) for *H. canabinus* and *V. colorata* stems are shown in Figure 4.

Other energy parameters detected in the two samples are presented in Figure 6. Which clearly provide an indication that both plants have low heating potential as the energy densities and calorific values were quite low.

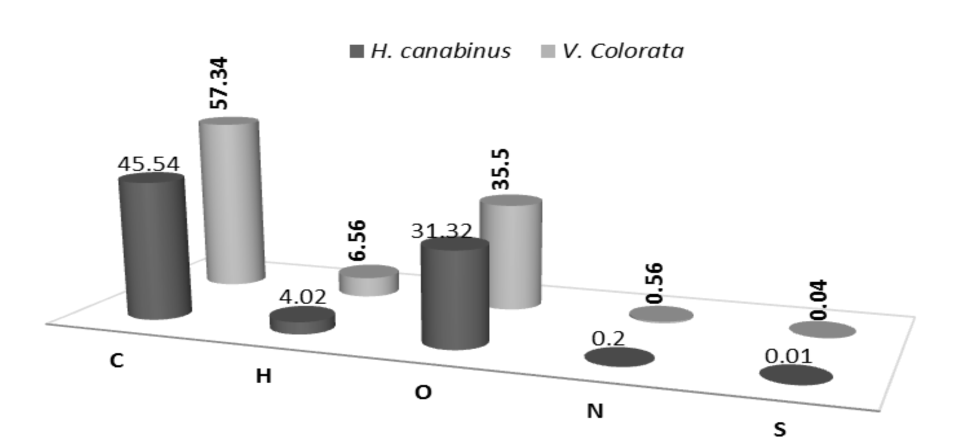

Figure 3: Ultimate Analysis of *V. canabinus* and *V. colorata (%)*

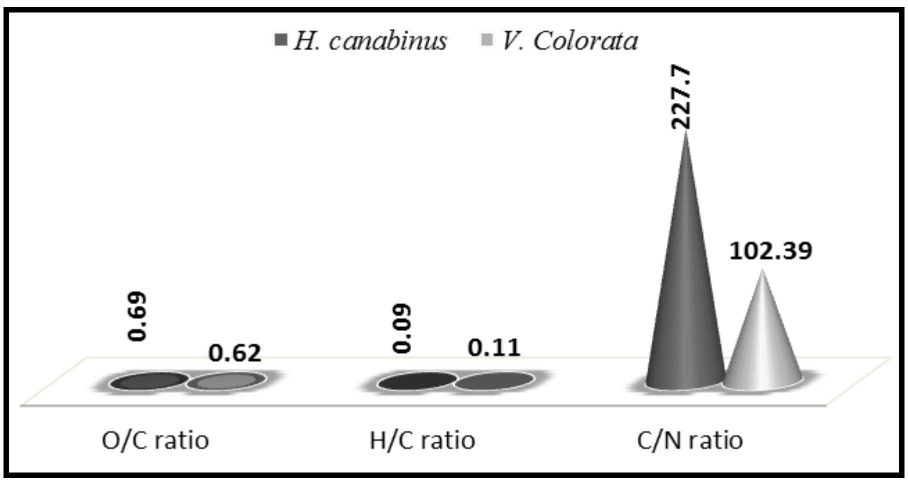

Figure 4: O/C, H/C and CN ratio of *H. canabinus* and *V. colorata* stem

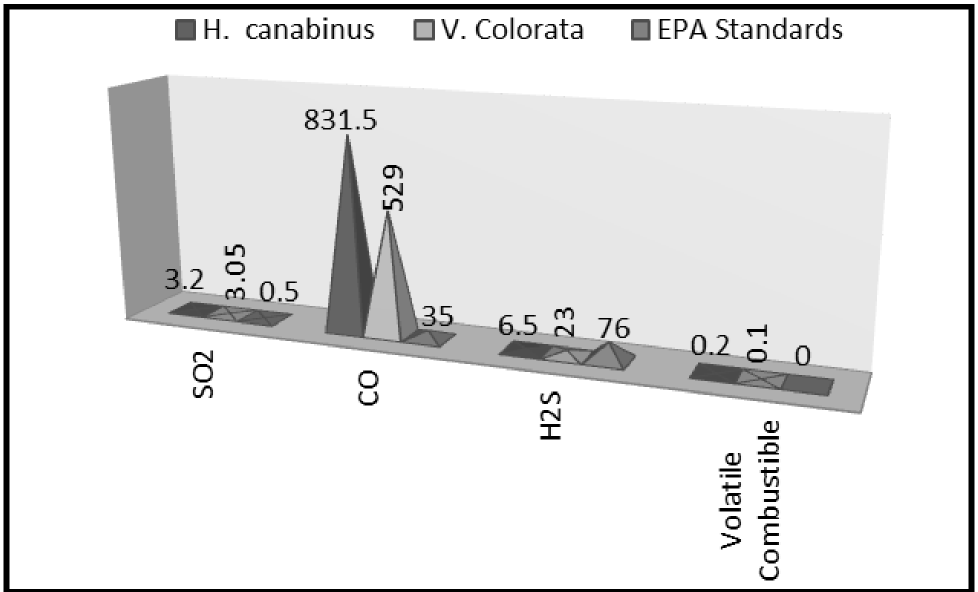

Figure 5: Concentration (mg/m^3) of gasses detected on burning *H. canabinus* and *V. colorata* stems.

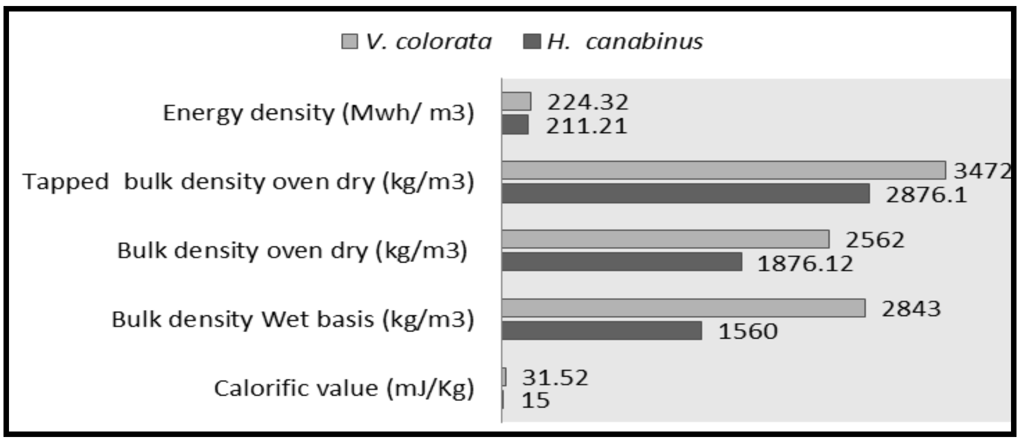

Figure 6: Other energy parameters of *H. canabinus* and *V. colorata* stems

DISCUSSION

The volatile matters detected in the samples are relative high, which justify why they are widely used as sources of sustainable flame. Some researchers (Loo and Koppejan, 2008) opined that when the volatile matters detected is high; it signifies easy ignition and a proportionate increase in flame length. It also indicates that during combustion, most plants will volatilize and burn in the gaseous phase. However, the *H. canabinus* with volatile components of 83.35% will produce more flame. The relatively high dry matter contents of 85.00% for *H. canabinus* and 90.92% for *V. colorata* further justify the high combustion potentials of the plants.

The ash content of 8.60% and 4.65% *H. canabinus* and *V. colorata* respectively is a lot higher than European normal standard of <1.5% for biomasses reported by Akowuah *et al.* (2012). While the moisture contents (MC) lies between 7.53% and 9.48 % which is well below the limit of 10-12% recommended by Austria and German standards for fuel pellets and briquettes (DIN, 1996; ONORM, 2003). The low MC enhances the ignition ability which further heightens the combustion quality and helps reduce objectionable smoke and toxic gases release (Godbout *et al.,* 2012).

Fixed carbon is another very important energy parameter detected in this work. *V. colorata* with maximum value of 8.69% is actually low when compared to values for fixed carbon reported in similar work on rice husk ash of 15.7% (Efomah and Gbabo, 2015; Musa, 2007) and other related biomasses (kenaf grass -17.0%, neem wood -12.9%, mango wood-11.36%, and corncob-11.36%) (Saidur *et al*., 2011). Fixed carbon is not necessarily equal to the total amount of carbon (ultimate carbon) in the plants because a significant amount is released as volatile hydrocarbons components. This is confirmed by the value of elemental composition reported as ultimate carbon to be 57.34% and 45.54% in *V. colorata* and *H. canabinus* respectively. This parameter provides a rough estimate of the heating value of a fuel biomass and acts as the main heat generator during combustion. Thus, the higher the carbon content of a biomass the more likely that the species would have higher heating value (Akowuah *et al*., 2012).

The sizeable quantity of carbon contents in Figure 4.0, with the H/C ratio of 0.09 for *H. Canabinus* when compared to *V. colorata* having H/C ratio of 0.11 confirms it has a higher heating value. On the other hand, the average O:C and H:C ratios of 0.68 and 0.10 respectively in both samples gives a slightly low level of carbon resulting in low calorific values in the plants which has a remarkable influence on the heating values of the samples under study. The C: N ratio will help in determining the appropriate energy conversion process in the biomasses, which will further assist in proposing a pathway for conversion of the energy of the biomass of these plants into more useful energy source. Similarly, the concentration of the SO_2, CO, H_2S detected are indicated in Figure 5, with SO_2 average concentration obtained in the two samples to be above 3.00mg/m^3, which is much higher than the EPA standard of 0.5mg/m^3 for SO_2 gases.

The nitrogen contents in both plants is within the limit of ≤ 0.6% set by the Austria National Standard for Pellet and Briquettes (ONORM M 7135, 2003) and further conforms to limit of ≤ 0.3% set by the German National Standard for Fuel Pellet (DIN 51731, 1996). The sulphur contents in both samples were lower than the limits set by the Austria and German National Standards for Fuel Pellet and Briquettes (Sulphur content ≤ 0.08%). The low sulphur and nitrogen contents in both samples are low (Figure 3) which is good as there will be minimal release of sulphur (SO_X) and nitrogen (NO_x) oxides into the atmosphere on combustion, this is confirmed from the low concentration of SO_2 detected, averaging 3.13 mg/m^3 (Figure 5) for both samples detected from the smoke emitted. Similarly, H_2S gas detected from burning the *H. Canabinus* and *V. colorata* stems were 6.50 and 23.00 mg/m^3 which are still low compared to EPA Maximum Standards 76.00mg/l (USEPA, 2016). This further point to the fact that the use of the plants as sources of light owing to the bright flame they produced makes them environmentally friendly.

From Figure 6, the calorific or heat values of both samples is 15 mJ/kg for *H. canabinus* and 31.52 mJ/kg for *V. colorata*. This is within the range of values obtained in coconut shell-20.00mJ/kg, groundnut shell-19.20mJ/kg, eucalyptus-19.35mJ/kg, softwoods-19.80mJ/kg, hardwoods-19.00mJ/kg, switch grass-19.90mJ/kg (Saidur *et al.,* 2011), but slightly below *Gmelina arborea* = 32.79mJ/kg, *Terminalia superba* = 32.69mJ/kg, *Triplochiton scleroxylon* = 32.79mJ/kg reported (Adegoke *et al.*, 2014). The reason for high calorific value could be traced to high carbon (ultimate carbon) content suggested by researchers (Kricka *et al., 2012)*, who recounted that the calorific value of fuel increases with similar increase in carbon level. This is confirmed by the significantly high O: C and H: C ratios obtained in the result of this work, which falls within the calorific value of solid fuels was reported (McKendry, 2002) using a Van Krevelen diagram from which higher proportion of hydrogen and oxygen reduces the energy value of biomass fuel than fossil fuel (coal).

From Figure 6, the loosed oven-dry and tapped oven-dry bulk densities of *V. colorata* are higher than that of *H. canabinus*. This suggests that *V. colorata* is more likely to have higher energy per unit volume. If all other factors remain constant, it will burns for a long period of time then the *H. canabinus* and other biomasses used for that purpose.

CONCLUSION

Volatile matter contents in *V. colorata* and *H. canabinus* was the major parameter of interest in this research, as it justify the use of these plants by the indigenous communities as sources of light owing to the bright flame they produce.

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