Elemental and Energy Characteristics of *Castenea sativa* Seed

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Abstract
This study investigated the proximate and elemental compositions, gross calorific values (GRV) and net calorific values (NRV) of the seed of Castenea sativa as possible biomass for renewable energy source. The moisture content was determined to be 2.06%. The elemental analysis revealed the presence of carbon, oxygen, hydrogen, nitrogen, with carbon at 52.05% and oxygen 29.48% being the most prominent. The net calorific value of the seed is found to be 12.38 MJ/Kg. These results can help in the provision of a theoretic base and statistics to support the further exploitation of Castenea sativa seed as biomass source renewable energy.
***Keywords**; Renewable energy, elemental analysis, biomass, castenea sativa, combustion.*

Introduction

Renewable energy sources are receiving great attention owing to their environmental friendliness and the undesirable environmental impacts of burning of fossil fuel that is set to deplete soon. Renewable energy sources like plant biomass due to their accessibility, easy processing abilities, and environmental friendliness are measured the utmost attractive of all available source of renewable energy. Plant biomass is commonly available in sub-Saharan Africa, particularly Nigeria because of its favorable climatic conditions. Nigeria, notwithstanding its abundant hydrocarbon reserve is making moves to diversify her economy and generate more income from sources other than oil. The prospect of transforming easily obtainable biomass materials into different forms of fuel is most attractive (Gajera et al., 2022). Biomass of different kinds, although consisting of same major constituents, has different compositions and has been explored as an alternative to fossil fuel.

The pyrolytic characteristics of plant biomass including *Phragmites australis, Malus domestica, Putranjiva roxburghii,Cassia fistula* and several others have been reported. *Phragmites australis, M domestica* and *C. fistula* biomass had great potentials as feedstock to produce admirable quality fuels and improved chemicals (Zhao et al., 2011; Sahoo et al., 2020). Plant biomass are exceptional energy sources and have been used as briquette for heating majorly for their renewable nature; low cost and low emissions of carbon and sulfide oxides. (Liu et al., 2021)

Materials and methods

Sample collection and preparation

Castenea sativa seed was collected from the premises of The Federal Polytechnic Ilaro, Ogun State, Nigeria. Two-kilogram of the seed sample was sun-dried, pulverized using an electric blender, and defatted with n-hexane in a Soxhlet extractor. The defatted sample was sun-dried, sieved with 1 mm sieve and stored for further analysis in a polythene bag.

Proximate Analysis

The ash content, moisture and volatile matter of deoiled *C. sativa* were determined using to ASTM D 3173 and ASTM D 3175 and ASTM D 3174 protocol. The fixed carbon content was calculated by the difference.

Gross calorific value (GCV)

Finely powdered C. sativa (0.5 g) was compressed into a tablet using a mechanical pelletizer. Adiabatic bomb calorimeter was used to determine the gross calorific value (GCV). At a pressure of 3.4 Mpa the product was oxidized by combustion in an adiabatic bomb containing oxygen.

Net calorific value (NCV)

NCV was calculated from GCV using the equation of Koppejan& Van Loo, 2012. Where thermal difference between gas and water = 2.444, at 25ºC, 8: 936 = ie: molecular mass (MM) relationship between water (H_2O) and hydrogen (H), where NCV = Calorific value, GCV= Gross value calorific, H = Concentration of hydrogen in C. sativa in wt.%, and w = Moisture content of C. sativa in wt.%.

Gross calorific value (GCV) of deoiled *C. sativa*
Finely powdered *C. sativa* (0.5 g) was pressed into a tablet with the use of a mechanical pelletizer. Gross calorific value (GCV) was determined by using an automatic adiabatic bomb calorimeter (Parr 100 Calorimeter). At a pressure of 3.4 Mpa the product was oxidized by combustion using oxygen containing adiabatic bomb**.**

Net calorific value (NCV) of deoiled *C. sativa*

The NCV was calculated from the GCV using the equation by Koppejan and Van Loo, 2012.

$$NCV = GCV\ x\left(1-\frac{w}{100}\right) - 2.444\ x\left(\frac{w}{100}\right) x\ 2.444\ x\ \left(\frac{H}{100}\right) x\ 8.936\ x\left(1-\frac{w}{100}\right) MJ/kg$$

Where Enthalpy difference = 2.444, between gaseous and liquid and water (H_2O) at 25^{o}C, 8.936 = $\frac{M_{H2O}}{M_{H_2}}$, i.e: the molecular mass (MM) relation between Water (H_2O) and hydrogen ($H_{2)}$, where NCV = Net calorific value, GCV = Gross calorific value, H = Concentration of hydrogen in *C. sativa*in wt %, and w = Moisture content of *C. sativa*in wt %.

CHN Analysis of deoiled *C. sativa*
CHN analysis was executed on a series II CHNS/O Analyzer (Perkin Elmer) serial number 241N9022721

Ash elemental composition of deoiled *C. sativa* by XRF
Table 1: Results and discussion

Gross calorific value (MJ/kg)	20.95
Net calorific value (MJ/kg)	12.38
Elemental analysis (wt.%)	
Carbon	52.05
Nitrogen	15.09
Hydrogen	3.38
Oxygen (by difference)	29.48
Proximate analysis (wt.%)	
Volatile matter	10.20
Ash	2.89
Moisture	2.06
Fixed carbon (by difference)	74.13

* *Calculated by difference; FC = 100 – (MC+AC+VM). O = 100 – (C + H + N + S)*

The moisture content of *C. sativa* was found to be 2.06%. Sugarcane bagasse and black gram straw has moisture contents of about 5.36 and 5.50%, respectively, which are higher than that of *C. sativa.* Thermal conversion requires a low-moisture biomass material, while a high-moisture biomass material is better suited for hydrothermal or enzymatic processes, as it is recommended by Chutia et al. (2013), moisture content analysed is 2.06% which is within the desired range (< 10%). Volatile matter is a major parameter which affects the combustion process significantly. The literatures show that there are biomass that has up to 2.5 times volatile matter than that of coal which affects its igniting and combusting conditions (Holtmeyer et al., 2014). C. sativa contain low volatile matter 19.2% which means there will be less smoke or no smoke during combustion.

Biomass combustion has ground ash as its major waste. The amount of waste generated is dependent majorly on the type of material in use. Ash content of C. sativa was found to be 2.89%. This shows that it is good enough to be pyrolyzed because it reacts high and is easy to remove from fire. High ash content can lead to insufficient combustion; leading to high cost operation, issue of waste disposal issues, and low conversion rates (Hiloidhari et al., 2018). The ash content was found to be 2.89 which is still within the range of <5% (Walkley, 1947).

Fixed carbon content indicates the quantity of organic material that will turn to coke in combustion process. This ratio indicates that the fuel will burn in two stages. Having a value of combustion coke and pyrolysis. However, the combustion will last longer because these fuels burn through explosions, these fuels will combust in form of residues (Sadiku et al., 2016). C. sativa has a specific carbon content of 74.13%.
The elemental analysis results revealed that the major elements present were carbon and oxygen, which were presented to be 52.05 and 29.48% respectively. Oxygen content will likely be high owing to the occurrence of oxygenated content, such as hemicellulose, cellulose. C. sativa has significant amount of nitrogen, 15.09% so it produce toxic emissions of NO_X during the thermochemical conversion process (Wang et al., 2017).
Thermo-physical parameter is an important parameter that is dependent on the Net caloric value which shows energy prospective of the materials. This particular parameter explains the reason for evaluating the quality of fuel as an energy source. As Net calorific value is related to moisture, so also is dependent strongly on the chemical composition of the biomass (Panepinto et al. 2014) *C. sativa* has calorific value of 12.37 MJ/kg which is higher than the original coal (10.56 MJ/kg) making this seed a prospective material favourable for a clean energy production (Jayaraman et al., 2017)

Conclusions

The calorific values obtained was12.37 MJ/kg, making this seed an attractive renewable energy source. The low-moisture content makes it a suitable material for thermal conversion. The low ash content makes the seed it is moderate enough to make it a possible feedstock for thermal processes. The biomass under study contains carbon, hydrogen, nitrogen and oxygen in amount comparable to those existing values in literature. This analysis shows that C. sativa has energy generating potentials of biomass fuel.

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