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ENERGY POTENTIAL OF OIL PALM MESOCARP AS A RENEWABLE SOLID FUEL

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ABSTRACT

The increasing demand for sustainable energy has intensified interest in agricultural residues as alternative solid-fuel resources. Oil palm mesocarp, a lignocellulosic residue generated during palm oil extraction, represents a potential feedstock for renewable energy production, particularly in oil palm-producing regions. This study evaluated the energy potential of oil palm mesocarp as a renewable solid fuel by characterizing its proximate composition and calorific value. Moisture content, volatile matter, ash content, and fixed carbon were determined using the analytical procedures reported in the study, while calorific value was measured using a bomb calorimeter in accordance with ISO 18125. The results showed that oil palm mesocarp had a moisture content of 8.36%, volatile matter of 71.48%, fixed carbon of 15.34%, and ash content of 4.82%. Its calorific value was 19.76 MJ/kg, indicating appreciable energy content and potential suitability for solid-biofuel applications. The relatively low moisture content suggests reduced drying requirements, while the high volatile matter content indicates favorable ignition characteristics. The measured ash content also suggests a comparatively modest inorganic residue fraction following combustion. In comparison with the conventional solid fuels discussed in the study, the calorific value of oil palm mesocarp was comparable to that of some wood fuels, although lower than that of wood charcoal. These findings demonstrate the potential of oil palm mesocarp as a renewable solid-fuel feedstock and support its valorization as an agricultural waste-to-energy resource. Further investigation of briquette durability, combustion emissions, and performance under controlled operating conditions is recommended to establish its practical applicability for domestic and industrial energy systems.

Keywords: Oil Palm Mesocarp; Biomass Energy; Renewable Solid Fuel; Proximate Analysis; Calorific Value; Agricultural Residue; Waste-To-Energy.

1 INTRODUCTION

Energy. It is an integral parts of human promotion, and it greatly affects socio-economic development, quality of life of the consumers and national security. The world is facing the challenge of satisfy increasing requirement of energy. The alternative source of energy is particularly important in this regard. Renewable energy sources in the form of biomass, energy from water (hydropower), the sun (solar energy) and the wind (wind energy) are attractive options [1]. *i*Biomass

*i*energy *i*contributes *i*to *i*rural *i*development *i*and *i*energy *i*security, [2]. Biomass *i*energy *i*is *i*derived *i*from *i*organic *i*materials *i*such *i*as *i*plants, *i*animals, *i*and *i*their *i*by-products, *i*which *i*can *i*be *i*converted *i*into *i*usable *i*forms *i*like *i*heat, *i*electricity, *i*and *i*biofuels. *i*These *i*materials *i*include *i*agricultural *i*residues, *i*wood, *i*animal *i*manure, *i*and *i*municipal *i*waste. *i*Biomass *i*is *i*considered *i*renewable *i*because *i*it *i*is *i*replenished *i*through *i*natural *i*biological *i*processes *i*within *i*a *i*relatively *i*short *i*time *i*frame *i*[3][4].

Oil palm mesocarp is among the various agricultural wastes available. It is a waste obtained from the processing of oil palm [5]. Nigeria is among the world's highest producers of oil palm and produces great amount of oil palm mesocarp yearly [6]. This biomass though plentiful is normally under exploited or completely wasted. It is said to have a relatively high lignocellulosic content and a high calorific value, therefore it would be suited for briquette production [5];[7].

The objective of this study is to evaluate the energy potential of oil palm mesocarp as a renewable solid fuel based on its proximate characteristics and combustion properties.

The aim of this study was to evaluate the energy potential of oil palm mesocarp as a renewable solid-fuel feedstock through the characterization of its proximate composition and calorific value, and to assess its suitability for potential biofuel applications in comparison with conventional solid fuels.

2 MATERIALS AND METHODS

2.1 Collection and preparation of oil palm Mesocarp

The *i*collection *i*of *i*OPM *i*begins with *i*harvesting *i*mature *i*fresh *i*fruit *i*bunches *i*(FFB) *i*from *i*oil *i*palm *i*trees. *i*Proper *i*harvesting *i*ensures *i*optimal *i*oil *i*yield *i*and *i*fiber *i*quality. *i*The *i*fruits *i*are *i*detached *i*from *i*the *i*bunches *i*manually *i*or *i*mechanically *i*before *i*processing.

OPM *i*is *i*obtained *i*during *i*the *i*mechanical *i*extraction *i*of *i*crude *i*palm *i*oil. *i*After *i*sterilization *i*and *i*digestion, *i*the *i*fruits *i*are *i*pressed, *i*producing *i*a *i*residue *i*known *i*as *i*press *i*cake, *i*which *i*contains *i*fiber, *i*palm *i*kernel *i*nuts, *i*and *i*residual *i*pulp *i*[8]

The *i*separation *i*of *i*mesocarp *i*fiber *i*from *i*palm *i*kernel *i*nuts *i*is *i*achieved *i*through, *i*manual *i*sorting *i*in *i*small-scale *i*mills *i*and *i*mechanical *i*separation *i*using *i*fiber–nut *i*separators *i*in *i*industrial *i*settings.

The *i*separated *i*fiber *i*is *i*further*i*cleaned *i*to *i*remove *i*dirt, *i*sand, *i*and *i*oil *i*residues. *i*Washing *i*and *i*screening *i*processes *i*improve *i*fiber *i*quality *i*and *i*suitability *i*for *i*briquetting *I*[8]

Processing *i*of *i*Oil *i*Palm *i*Mesocarp *i*for *i*Briquetting *i*Involves *i*processes *i*such *i*as: *i*size *i*reduction, *i*drying *i*of *i*fiber, *i*removal *i*of *i*residual *i*oil *i*and *i*pretreatment…

2.2 Proximate Analysis

Moisture Content: Moisture *i*content *i*was *i*determined *i*according *i*to *i*(ASTM *i*E872-24), *i*using *i*the *i*oven-drying *i*method

$$MC(\%)=\frac{Wi\text{-}Wf}{Wi}x100 \quad (1)$$

Where: *i*

MC = *i*moisture *i*content

Wi *i*= *i*initial *i*weight

Wf *i*= *i*final *i*weight

Ash Content: Ash content is the percentage of inorganic residue remaining after a fuel sample has been combusted under specified conditions. It provides an indication of the non-combustible mineral fraction of the biomass and is an important parameter in evaluating fuel quality and potential ash-related operational challengesAsh *i*content *i*was *i*determined *i*according *i*to *i*(ASTM *i*E872-24), *i*using the standard *i*gravimetric *i*furnace *i*method. [10; 11]

$$Ash\ iContent\ i(\%)\ \frac{Mass\ iof\ iAsh\ icontent}{Mass\ iof\ iOriginal\ iSamples} \quad (2)$$

Volatile Matter: Volatile matter (VM) refers to the proportion of gaseous and vapour products, excluding moisture vapour, released from a fuel sample when heated under specified conditions in the absence of air. It is an important indicator of the fuel's devolatilization characteristics and can help explain its ignition and combustion behaviour. Volatile matter was determined according to ASTM E872-24. The Volatile matter of the samples was the determined as given by equ. 4

$$Volatile\ Matter\ (\%) \frac{Mass\ loss\ during\ heating}{Original\ Mass} \quad (3)$$

Fixed Carbon: Fixed carbon content was determined according to ASTM E870-24 by the difference method after determining the moisture content, volatile matter, and ash content of the briquette samples. The Fixed content of the oil palm mesocarp was the determined as given by equ. 4

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

Where:

MC = Moisture content

VM = Volatile matter

AC = Ash content

Calorific Value: Calorific value represents the amount of heat energy released during the complete combustion of a unit mass of fuel. The calorific value of the oil palm mesocarp was determined according to (ISO 18125, 2017) using a bomb calorimeter. The calorific value of each sample was subsequently obtained from the measured temperature rise and expressed in MJ/kg. The Calorific Value of the samples was the determined as given by equ.5

$$CV = (W \times \Delta T - e)/m \quad (5)$$

CV= Calorific value

W = Calorimeter energy equivalent (kJ/°C)

ΔT = Temperature rise (°C)

e = Total correction (ignition wire, cotton thread, acid formation) (kJ)

m = Sample mass (kg)

3 RESULTS AND DISCUSSION

The Table 1 shows result for proximate data of the oil palm mesocarp. These values demonstrate that oil palm mesocarp possesses favorable physicochemical properties for briquette production and confirms its suitability as a renewable biomass fuel.

The relatively low moisture content (8.36%) indicates that the biomass required minimal drying before densification. Moisture contents below 10–12% are generally considered ideal for biomass briquetting because they promote better compaction, improve dimensional stability, and enhance combustion efficiency [14; 15]. Similarly, the ash content of 4.82% is within the acceptable range reported for agricultural biomass fuels, suggesting that the mesocarp would generate relatively low ash residues during combustion [16]

The Oil palm mesocarp also exhibited a high volatile matter (71.48%), indicating good ignition characteristics and ease of flame propagation. Although high volatile matter promotes rapid ignition [17], excessive values may increase flame intensity and smoke emission; however, the measured value falls within the normal range reported for lignocellulosic biomass residues[18]. Furthermore, the fixed carbon content (15.34%) indicates the biomass possesses sufficient carbonaceous material capable of sustaining combustion after volatile gases have been released. Higher fixed carbon generally contributes to longer burning duration and improved heat retention [16].

The icalorific ivalue iof i19.76 iMJ/kg iconfirms ithat ioil ipalm imesocarp iis ian ienergy-rich ibiomass isuitable ifor irenewable ifuel iproduction. iThis iheating ivalue icompares ifavorably iwith imany iagricultural iresidues ireported iin ithe iliterature iand ifalls iwithin ithe irange irecommended ifor idomestic iand iindustrial ibiomass ibriquettes I[17; 19].

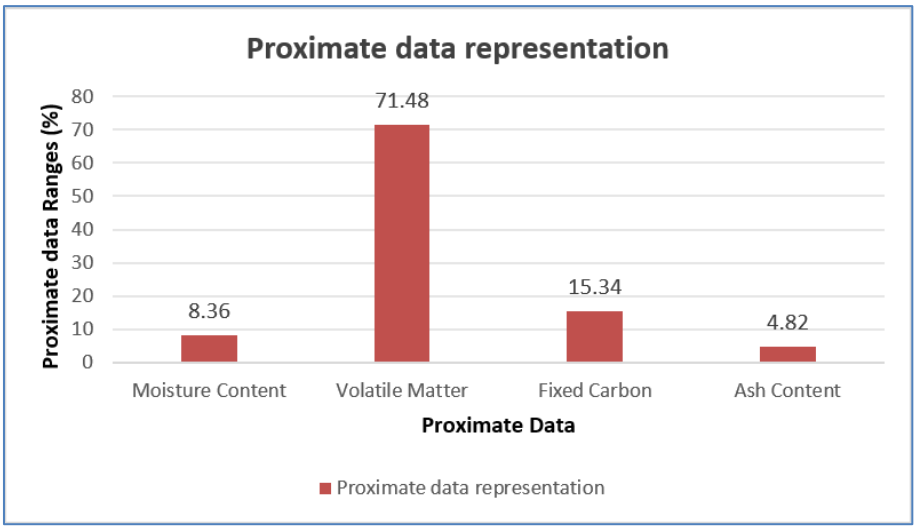


Figure 1: Result *I*for Proximate *I*Data *I*of *I*the *I*oil Palm Mesocarp

3.1 Comparing energy content of Conventional Fuel

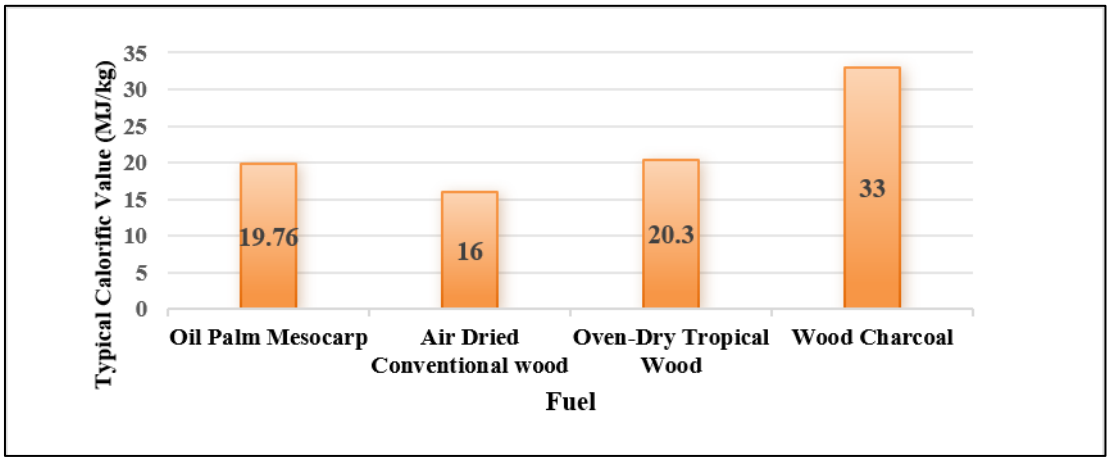


Figure 2: Typical *i*conventional *i*fuel *i*Calorific *i*Value

Oil palm mesocarp energy content compared with the control samples which are the conventional solid fuels. According ito iFAO, ithe iAir-dried iconventional ifuel iwood irecorded ia icalorific ivalue iof i16MJ/kg iand i16.7- i20.3MJ/kg ifor ithe iOven-dry iTropical iwood. iIndicating ithe iOil ipalm iMesocarp poses a good proportion of ienergy icontent iat 19.76MJ/kg. iHowever, icomparing ito ithe icalorific ivalue iof iWood icharcoal, iapproximately i33MJ/kg iwas ireported iand ithis ihigher iCalorific iValue iis iattributed ito icarbonization iProcess. [20; 21]. The icalorific ivalue ifrom ithe iwood icharcoal ido inot ireduce ithe irelevance iof ithe ioil ipalm iMesocarp because ithese biomass has inot been icarbonized ito iconserve ienergy iand ialso ioffers iWaste ito iEnergy ialternative. Non-carbonized ibriquettes ipossess ienergy icontent ithat ican ibe icompared iand, iin imost icases, iserve ias ian ialternative ifuel iwood ibut iusually ilower ithan icharcoal. [22]iCarbonization iincreases iEnergy icontent iof icharcoal. The Oil palm mesocarp possesses a substancial fraction of the energy content of conventional solid fuels while being renewable and derived from an agricultural residue.

4 CONCLUSION

This study evaluated the energy potential of oil palm mesocarp as a renewable solid fuel through proximate renewable solid fuel through proximate analysis and calorific value determination. The mesocarp had a moisture content of 8.36%, volatile matter of 71.485, afixed carbon of 15.34%, and ash content of 4.82%, with a calorific value of 19.76 MJ/kg. The

low moisture content means little drying is needed before use, the high volatile matter indicates easy ignition, and the modest ash content suggests limited residue after combustion.

The calorific value is comparable to that of air-dried wood (about 16MJ/kg) and falls within the range reported for oven-dry tropical woods (16.7-20.3 MJ/kg), though it is lower than wood charcoal (33 MJ/kg). Because the mesocarp is uncarbonized, it offers a waste-to-energy option that avoids the energy losses of carbonization. These findings support oil palm mesocarp as a potential renewable solid fuel biomass, particularly in oil palm-producing regions such as Nigeria.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare no conflicts of interest in this work.

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APPENDICE A: *I*OIL PALM MESOCARP PROXIMATE*I*DATA*I*AT*I*RAW*I*STATE

Sample	**Moisture icontent i(%)**	**Volatile imatter i(%)**	**Fixed iCarbon i(%)**	**Ash iContent(%)**	**Calorific ivalue i(MJ/kg)**
Oil iPalm iMesocarp	8.36	71.48	15.34	4.82	19.76