The Potential of Coconut Shell as Biofuel

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Abstract. The potential of coconut shell as a crop residue and its use as a biofuel has been ignored by our local communities and researchers, despite its importance as an alternative fuel in homes and small-scale industries. Today due to the increasing demand and cost of petroleum energy caused by decreasing supply and cost of firewood as a result of deforestation, demand and increasing population, coconut shell as a valuable biofuel must be viewed with seriousness. When coconut shell is used as a fuel, this attempt to reduce the amount of CO_2 in the atmosphere and sanitizes the environment of the injurious hard shell in addition to providing alternative and better source of fuel than fuelwood and other traditional fuel among the poor rural communities especially in developing countries. This reduces the demand and cost of fossil fuel as domestic energy. In this research, the potential of coconut shell was investigated by measuring a number of parameters ranging from moisture content, ash content, density and caloric value and specific heat capacity. Moisture content is considered as the most important parameter of the five parameters measured. The result of this research indicates a moisture content of approximately 9%, ash content 1.1%, density 0.98cm^3, calorific value of 17.7mj/ kg and a fuel value index (FVI) of 810. Among all the agricultural crop resources namely, rice husk, sugarcane biomass, maize straw, rice straw, coconut frond and leaves, coconut shell has the highest biomass quality and the most utilized since it can be processed into charcoal due to high lignin content. Conclusively, considering the above measurement and results obtained from the coconut biomass as a biofuel, it is essential and necessary to encourage the use of coconut shell as a domestic fuel, particularly in the rural areas of developing countries where petroleum energy, deforestation and fuel wood scarcity is a challenge.

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1. Introduction:

Biofuel is a fuel obtained from biologically degradable materials, either from plants or animals. Biofuel is of three types when processed and may be in the form of solid, liquid or gas. Solid biofuel is in the form of biomass obtained directly from farmland such as rice hull, coconut shell or corn stalk, or in the form of fuelwood. Malakini et al. (2014) reported that biomass; mainly firewood and charcoal contribute over 40% of Malawi's total energy demand. Other sources like electricity, petroleum products, coal and other renewable energy sources play a minor role and account for only 7% of the energy use.

Solid biofuel may also be waste materials such as sawdust and rice hull which are processed into a briquette. Yahaya and Ibrahim reported that in most developing countries like Nigeria recycling of waste agricultural products like rice hull into useful products is rarely practiced; this results into pollution and blockage of drainages and waterways and heaps of refuse in streets causing floods and sometimes epidemic diseases. Bakker (2000) reported rice hull to have some disadvantage over other solid fuel such as high silica causing wearing in processing machines, high volatile matter, and ash than in wood, thereby causing a barrier for energy conversion (Jenkins, 1998). Its high ash, alkali and potassium content causes agglomeration fouling and melting in the components of combustion or boilers (Bakker, 2000). Klass (1998) suggested that the solution to solve barriers in energy conversion from rice husk is pretreatment through mechanical, physical and chemical means and bioprocessing. Tillman (2000) suggested combining rice hull with other fuels that are lower in alkali and chlorine is a step forward. Liquid biofuels are generated through a process known as fermentation to produce alcohol or oil from plants or animals which are esterified_to produce a liquid fuel called biodiesel.

The gaseous biofuel is produced by a process known as methanation, where degradable materials are digested anaerobically to produce methane, which is a gas fuel.

This research intends to investigate coconut shells as a solid biofuel. Coconut is produced in 92 countries worldwide on about more than ten million hectares. Indonesia, Philippines, and India account for almost 75%

of world coconut production with Indonesia being the world's largest coconut producer.

A coconut plantation is analogous to energy crop plantation, however, coconut plantation is a source of a wide variety of products such as coir yarn for the weaving of coir mats, fiber mats, rugs, and carpets (Kürsten, 2015), organic fertilizer, animal feed, fuel additive for cleaner emissions and healthy drink etc.

The coconut fruit yield 40% coconut husk which contains 30% fiber, with dust making up the rest. The chemical components of coconut husk are of cellulose, lignin, pyroligneous acid, gas, charcoal, tar, tannin, and potassium. Coconut husk has higher lignin and cellulose content. The material contained in the casting of the husk and coconut fibers are resistant to bacteria and fungi.

Coconut husk and shells are an attractive biomass fuel and are also a good source of charcoal. The major advantage of using coconut is that it is a permanent crop and available around the year so there is constant supply whole year. Activated carbon is manufactured from coconut shell which is regarded to be extremely effective for the removal of impurities in waste water treatment processes.

Coconut shell is an agricultural waste and available in large quantities throughout tropical countries worldwide, in many countries, coconut shell is subjected to open burning which contributes significantly to CO_2 and methane emission. Tan et al. (2004) reported a reduction in net CO_2 emissions are estimated at 77-104 g/mj of diesel displaced by biodiesel Coconut shell is widely used for making charcoal. The traditional pit-method of production has a charcoal yield of 25-30% of the dry weight of shells used. The charcoal produced by these methods affects the quality and is often contaminated with extraneous matter and soil. The smoke that evolves from the pit-method is not only a nuisance but also a health hazard. The coconut shell has a higher calorific value of 20.8mj/kg and can be used to produce steam. Energy-rich gases, bio-oil, briquette, etc. are a good source of fuel particularly in rural areas where domestic fuel is a challenge.

It is to be noted that coconut shells and coconut husks are solid fuel and have the peculiarities and problems inherent in this kind of fuel. Coconut shells are more suitable for pyrolysis process as it contains lower ash content and high volatile matter content and available at a cheap cost. The highest fixed carbon content leads to the production of a high-quality solid residue which can be used as activated carbon in waste water treatment. Klass (1998) reported rice husk to contain about 30% -50% of organic carbon and a heat value of 13-16 Mj/kg. Coconut shell can be easily collected in places where coconut meat is traditionally used in food processing. Biofuel provides a solution to waste management by converting waste into usable energy.

Coconut husks have a high amount of lignin and cellulose and that is why it has a high calorific value of 3500-4000kcal/kg, Ash content 4%-5% and a moisture content of 15% (Yong et al., 2009). The chemical composition of coconut water consists of sugar, vitamins, minerals; amino acid and phytohormones (Yong et al., 2009), husks consist of, water-soluble 5.25%, pectin and related compounds 3.00%, hemicellulose 0.25%, lignin, 45.84%, cellulose43.44% an ash 2.22% (Young et al. 2009). The predominant use of coconut husks is in direct combustion in order to make charcoal; otherwise, husks are simply thrown away and can be injurious but can be transformed into a value-added fuel source which can replace fuelwood and other traditional fuel sources. In terms of availability and costs of coconut husks, they have good potential for use in a power plant.

The leftover fiber from coconut oil, coconut milk production and coconut meal is used as livestock feed. The dried calyx is used as fuel in a wood-fired stoves Coconut water is traditionally used as a growth supplement in plant tissue culture/micropropagation (Yong, *et al.,* 2009).

Alejandro (2002) reported that the Philippine households tend to use several cooking methods for reasons of convenience and taste. Charcoal is a preferred fuel for grilling chicken and fresh fish and often used in the rainy season as a primary or supplementary cooking fuel in rural areas because of the problem of accessing dry fuelwood (Alejandro et al., 2002).

2. Methodology:

Several parameters were examined on coconut shell biomass as a renewable source of energy. The parameters measured include:

2.1. Moisture Content

The moisture content of the coconut shell (husk) was determined as follows; 1000gms (1kg) of coconut biomass (husk and shell) was measured as an initial quantity using precision electric balance (model TL f00g). The initial quantity of 1000g (1kg) of the coconut biomass was placed on a metal tray and put into a moment drying oven at a temperature of 180^{0}C for six (6) hours to allow a loss in weight.

After six hours the sample was removed from the oven which was assumed to be dry by losing weight due to moisture (adhesive moisture). The dry coconut biomass was weighed again to determine the constant and final loss in weight (moisture content).

2.2. Percentage (%) ASH Content

The percentage of ash content (PAC) of the coconut shell was determined by heating 100 grams of the coconut biomass in a muffle furnace at a temperature of 200^{o}c for six (6) hours, adequate enough to allow burning. The burnt sample was allowed to cool, to observe the change in color and dust particle size. The sample weighing (100g) before burning was weighed using the electrical balance to determine the percentage quantity of ash. The percentage quantity of ash was determined by the formula;

xg/100g x100 =Ash content (%)

x= net weight (g).
100g=initial weight (g).
100=percentage.

2.3. Density

The density of a material is its mass per unit volume (mass/vol.). 100 grams of coconut biomass was measured to determine the mass using the electronic weighing machine. The density of the sample was calculated by dividing the mass (kg) by volume (cm^3) of water or moisture displaced

Density=Mass (kg)/Vol. (cm^3)

2.4. Calorific Value (MJ/Kg^{-1})

The calorific value of coconut shells was determined using the percentage value of the ASH content and moisture content as suggested by Barnard (1985). The gross (higher) calorific value (HCV) or (HHV), which represents the amount of energy created when 1kg of absolutely dry wood is burned and all water created in the burning process is condensed. This was calculated through,

HCV =20.0 X (1-A-M) Mj/kg Where;
A = ASH content.
M = % moisture content.

The net (or lower) calorific value (L.C.V) which takes into account uncovered energy from the water vapors from inherent moisture and the oxidation of the hydrogen content is sometimes used. The lower calorific value (LCV) was LCV= 18.7 X (I-A-M) -2.5 x$Mjkg^{-1}$.

2.5. Value Fuel Index

The Fuel Value Index (FVI) was calculated using the formula suggested by Bhatt and Todaria (1992) as follows: Fuel Value Index (FVI) = Calorific Value X Density/ASH

2.6. Specific Heat Capacity (JKG^{-1})

The coconut biomass ash content was used to determine the specific heat capacity using the mixture methods, bomb calorimeters (kj/Kg) was weighed out of the casing.

It is then half-filled with water at room temperature (27^0c). The ash content was weighed and then placed in boiling water for about ten (10) minutes. The hot ash sample was quickly transferred into calorimeter and stirred properly for the final temperature to be recorded and substituted into the equation. The equation was used for the calculation of the value on specific heat capacity.

The calculation was as follows by the formula:

$$\frac{(\text{Mass of specimen x } 460) + \text{mass of water } (0.4 \text{ x } 27\ ^0\text{c})}{\text{Mass of sample x temperature}}$$

3. Results and Discussion:

Table 1: *Table Showing Loss in Weight of Coconut Shell Due to Moisture Content*

The initial weight of coconut shell (g)	*The weight of coconut shell after drying (g)*	*The difference in weight (g) and percentage (%)*
1000g	912	88 (8.8%)

In this result, the initial weight of 1000g produced a net weight of 912g, a difference of 88g over a period of six hours. This loss in moisture content was observed due to moisture content and possibly some volatile substances such as oil and tannins. The lost weight was equivalent to 8.8% of the total weight of the biomass.

This moisture content was observed to be solely adhesive moisture content rather than surface moisture content. A moisture content of 8.8%/kg is low and adequate enough for a good fuel, a moisture content of 15% was obtained by (bioresource.com/coconut shell). This can be compared to wood which ranges from 20%-25% /kg and 2%-7% in wood and charcoal respectively. Torgrip & Fernández–Cano (2017) indicated a moisture content of 0.034%, 0.026% and 0.011%. The differences in moisture content obtained in coconut shell can be attributed to the humidity of the environment where the research was carried out, Olorunnisola (2007) reported that coconut husk is known for a high affinity for water (hygroscopic). Therefore, higher moisture content is experienced in the husk than the shell

In this ecological zone where the research was carried out, coconut shell use as a biofuel is not popular and scarce compared to fuelwood which is the traditional domestic fuel. Therefore, coconut shell can serve as an economical and efficient domestic fuel for cooking and warming. This will reduce the effect of deforestation, carbon emission and the indiscriminate disposal of the injurious waste material.

3.1. ASH Content

The proportion of ash content was as low as 10g which represent about 1.09% indicating the coconut shell as a potential source of fuel. Mineral materials with low ash content were known to have high energy potential (James and Duke, 1983) An ash content value of 0.0015, 0015 and 0.0049 for three different fuel species on a dry weight basis (Torgrip & Fernández–Cano, 2017). Ash content influences the choice of the appropriate combustion technique and deposit formation. High ash content enhances the cost of storage, handling, and disposal of waste. Also, the ash content was observed to be odorless.

The European Commission (2008) reported that the fuel nitrogen content is responsible for nitrous oxide formation emissions which belong to the main environmental impact factor of solid biofuel combustion. An ash content of 0.7% to 2.5% in some tropical wood was said to be normal (charcoal ash may be higher).

Table 2: *ASH Content*

The initial weight of biomass	*Net weight as (g)*	*The difference in weight loss*	*The percentage of difference ASH content*
912	10	902	1.09

3.2. Density (g/cm^3)

The density of coconut shell was estimated to be 0.98g/ cm^3 in this research which means it is high enough as required of a basic density, however Madakson et al. (2012) obtained the density of coconut shell ash of 2.05g/cm ^{3} which placed the material as light compared to bagasse and silica with 1.8 and 2.2 g/cm^3 respectively. Olorunsola (2006) obtained a compressed density of 8.1g/cm^3 to 11.2 g/cm^3. A high bulk density is of an advantage because it represents high energy value and durability while low density gives rise to insufficient flow under gravity. The European Commission (2008) reported standard bulk density in wood, charcoal, and peat to be 300 to 550 kg/m^3, 200 to 300 kg/m^3 and 300 to 400 kg/m^3 respectively. Bulk density varies with moisture content and particle size; inadequate bulk density can be improved by briquetting.

Mass of coconut shell (g)	*The volume of coconut shell (cm^3)*	*Density (cm^3)*
98.9	100	0.98

3.4. Calorific value

The calorific value of coconut shells biomass was determined using the percentage value of ash content and moisture content. The gross Higher caloric value (HCV) or (HHV) is the amount of energy created when 1kg of absolutely dry wood is burned and all water created in the burning process is condensed, while the lower calorific (LCV) or (LHV) is the amount of energy created when 1kg of wood is burned and the water content of the fuel and water created in the burning process vaporize.

In this result, the values obtained for LCV and HCV was 18.02 MJ/g and 37.07 Mj/g respectively. Torgrip & Fernández–Cano (2017) reported a heating value of three materials 0.55 mj/kg, 0.44mj/kg and 0.17mj/kg. FAO (1990) reported that materials with low ash content and moisture content between 10% and 15%, like most briquettes from wood and agro-residues, the resulting caloric value are found in the range of 17-18 mj/kg range LCV; 15.4-16.5MJ/Kg. Given the above value, it indicates that coconut shell has a high caloric value as a fuel for both domestic and industrial use in this ecological zone of Nigeria. Although Nigeria is blessed with abundant renewable energy resources, there is currently a heavy reliance on fuelwood and fossil fuel.

The traditional sourcing of fuelwood for domestic and industrial use has been responsible for desertification in the arid zone and frontline states of Nigeria. NAP (2000), reported that Nigeria consumes well over 50 million metric tons of fuelwood annually at a rate that exceed the afforestation replacement program. Using coconut can also reduce the amount of carbon emission.

Table 3: *Showing Caloric Value of Coconut shell*

Mass of coconut shells (g)	*Ash content (g)*	*Moisture content (g)*	*Calorific value HVC (Mj/g*	*Calorific value LCV(MJ/g)*
912	10	88	18.02	37.07

3.5. Fuel Value Index (FVI)

This research obtained an FVI as follows:

FVI = Calorific Value X Density/Ash, therefore:

FVI=18.02 X 0.98/1.09 =17.66

FVI=17.66/1.09= 16.20

FVI=16.20 were estimated for 20gm of the fuel material, therefore for 1kg of the Coconut shell is equivalent to:

FVI=16.20 X 50 =810

FVI=810

This value of 810 is adequate enough to conclude that coconut shell has a high energy value. Bhatt and Todaria (1992) suggested that any material with high FVI but low ash content should be considered as a good fuel.

3.6. Specific Heat Capacity

Table 4: *Table Showing the Specific Heat Capacity of Coconut Shell*

Mass of coconut shells (g)	*Mass of water (c ^{3})*	*Temperature (^{0}c)*	*Specific heat capacity (Mj/ kg)*
912	100	27	18.40

The specific heat capacity in this research indicates a value of 18.40mj/kg which can be compared to that of rice hull which is 13-16 mj/kg. This value is adequate enough to consider coconut shell as a fuel. This means it takes about 18.40 joules of heat to raise 1 kg of coconut shell as biofuel in the production of steam, energy-rich gases, bio-oil, and biochar. Given this potential from coconut shell, it is valuable as a source of cooking energy to refugee camps, especially in displaced conflict areas of Middle East Asia and Africa, especially where this research was carried out in Borno State Nigeria. This will go a long way in solving the internally displaced person's energy crisis.

5. Conclusion:

This research reveals that coconut shell has the basic values required of a good fuel, such as high caloric value, low moisture content, low ash, low CO_2, no offensive odor and low velocity on combustion compared to rice hull and wood. Memory et al. reported that the maximum and best use of a biomass, like fuel wood depends on the type of stove or cooking appliance used. Therefore, where coconut shell is utilized as a fuel it will command a higher price than the traditional fuelwood thereby saving the people's income in addition to CO_2 free environment, reduced rate of deforestation and land degradation in Nigeria particularly in the Northern part of the country where the research was carried out. TC et al. (2002) observed coconut shell charcoal to command a high price than wood in the Philippines very high energy value which is very important for domestic and even significant for industrial purpose.

In Nigeria, the Federal government through the Energy Commission of Nigeria (ECN) has put in place the following programmed scheme of promoting optimal utilization of renewable energy resources with the view of reducing deforestation associated with fuelwood sourcing.

6. Recommendations:

This research is, therefore, recommending Coconut shells as an alternative source of biofuel which is cheap and environmentally friendly as well as acceptable domestic fuel. This is also an economic means of safe disposal of coconut shells being injurious when stepped on with barefoot. A training programmed scheme on renewable energy technics and biomass utilization scheme is recommended.

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