

Determination of Calorific values of coconut shell and cocoanut husk

Abstract

The coconut palm has a lot of uses. In this work, the calorific values of the shells and husks have been determined using a bomb calorimeter. The mean value obtained for the shell was 17.40 MJ/kg and that for the husk was found to be 10.01 MJ/Kg. Such high calorific values mean that these materials, which are normally considered as waste, have the potential of being used as energy sources. This will go a long way to ease pressure on traditional energy sources like wood, thereby preventing deforestation.

Keywords: Coconut shell, coconut husk, calorific value, bomb calorimeter.

1. Introduction

Coconut is a large palm that can grow up to 30 m tall, thrives on sandy soils and highly tolerant of salinity. It prefers areas with abundant sunlight and regular rainfall (750-2000 mm) annually. The coconut meat, which is the white edible part of the seed, is found inside the wall of the endocarp. Aside this it yields husks, shells, leaves and the stem, which are used domestically as raw materials for many products from fuel to building materials (Sonntag & Van Wylen, 1971). The husk is composed of fibres called coir with an inner shell known as the endocarp.

A lot of research has been conducted on the various applications to which the assorted components of coconut can be put. These include the use of its fiber in forming varied composites using several materials (Ali, 2011; Amoako, Mensah-Amoah, Sam, & Sackey, 2018), its application in enhancing engine performance and study of the emissions and combustion characteristics of coconut biodiesel in diesel engines (How, Masjuki, Kalam, & Teoh, 2014). The husks and shells can be used for fuel and also as a good source of charcoal. The roots of the coconut palm are used as dyes, mouth wash and medicine for dysentery. Currently in Ghana there is not much use for the shells and the husks and therefore after harvesting and the white part eaten or oil extracted, these parts (shells and husks) are discarded as waste material. In most parts of Ghana this poses a waste disposal problem as heaps can be found littered everywhere.

The commercial production of charcoal from the coconut shells will serve as an export commodity for coconut producing areas as these coconut shells are readily available across areas like the Central and Western Regions where small scale producers extract oil from coconuts.

Biomass in the energy production industry refers to any living biological material that can be used as fuel. It includes plant matter grown for use as biofuel or animal matter used for the production of fibers, chemicals or heat. Biodegradable wastes that can be burnt as fuel are also classified as biomass, but excludes organic materials which have been transformed by geological processes into substances such as coal or petroleum (Environmental and Energy Study Institute [EESI], n.d.). Gasification is the conversion of biomass into a gaseous energy carrier known as producer gas, a process based on partial oxidation at high temperature. The gas produced is mainly used for heat production and electricity generation and can be used as a synthesis gas in the industry to produce methanol or ammonia. The power resulting from gasification of the resultant gas is deemed to be a source that can be replenished naturally if the gasified compounds were obtained from biomass. Biomass is generally an important fuel for many small- and medium-scale industries in Africa that are engaged in ventures such as brick manufacturing, lime production, fish smoking, tobacco curing, beer brewing, coffee and tea drying.

A large proportion of energy used domestically in Ghana comes from firewood and charcoal (Jones & Childers, 2001). Such energy sources are not cheap and besides, their extensive use encourages deforestation, depletion of the ozone layer and causes greenhouse effect. This brings about global warming and its related effects. Energy issues have come to the forefront of national and worldwide policy makers because of the threat of climate change and the dangers of global warming. It has therefore become imperative to find an alternative and more efficient means of energy generation, either the generation of electricity using biomass or the use of more efficient methods for biomass combustion for cooking and drying of agricultural produce.

This work seeks to measure the calorific value of coconut shells and husk as a first step in determining its suitability as an alternative fuel for industrial and domestic use. Such materials are widely available and even discarded as waste.

2. Materials and Methods

A bomb calorimeter made from brass ensured that the combustion reaction occurred at constant volume, and used to determine the energy contained in the samples (cocoanut shells and husk shown in Figures 1a and 1b respectively) by quantifying the heat generated during its combustion. A schematic representation of the set-up is shown in Figure 2. Any heat exchange between the bomb calorimeter and the external environment is prevented by insulation.



a.

b.

Figure 1: a-Coconut shells; b-coconut husks

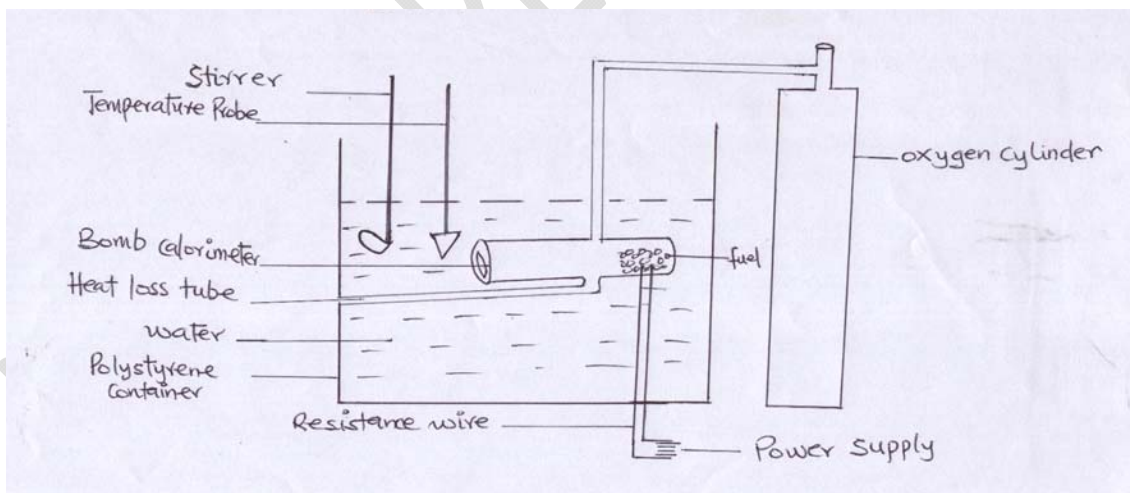


Figure 2: A schematic representation of the experimental set up.

The sample was put in the combustion chamber and ignited (by passing current through a resistance wire), after which the power source was shut off. Complete combustion of the fuel (sample) was achieved by passing gaseous oxygen into the combustion chamber. Incomplete combustion of the fuel would have taken place if the sample was

simply burnt in excess air as air contains more nitrogen than oxygen. The bomb calorimeter (Figure 3) was opened at one end where the sample was passed and then sealed with stainless screws and a silicone sealant to prevent water from entering. A heat loss tube was connected to the bomb calorimeter to transfer any excess heat outside. During the combustion process, the mass of each element remained constant.



Figure 3: Bomb calorimeter with resistance wire before being sealed.

2.1. CALORIMETER

The heat content, also known as the calorific value, is the amount of energy generated from the material undergoing the combustion. It is measured in units of energy per amount of material. In this work, the unit MJ/kg is used and the variables measured are the initial and final temperature T_0 and T_1 respectively.

The energy generated by combustion, Q_c is proportional to the calorific value and expressed in equations (1) and (2) as:

$$Q_c = Q_{water} + Q_{calorimeter} \quad 1$$

$$Q_c = (M_c C_c + Q)(T_1 - T_2) \quad 2$$

where M_w , M_c , C_w , and C_c are respectively the mass of water, mass of calorimeter, specific heat capacity of water and specific heat capacity of the calorimeter. To measure Q ($M_c C_c$) in equation (2), the bomb calorimeter was immersed in water and an electric heater used to raise the temperature of the water. Heating was done for 300 seconds while stirring. At equilibrium, the heat transfer equation expressed in equation (2) can be restated in equation (3), and the calorific value Q determined using equation 4. The value of Q was calculated using the substitutions of parameters given in Table 1.

$$\frac{V^2 t}{R} = (M_w C_w + Q)(T_1 - T_0) \quad 3$$

$$Q = \frac{V^2 t}{R(T_1 - T_0)} - M_w C_w \quad 4$$

Table 1: Values of parameters substituted in calculating the calorific value Q

Parameter	Value
Resistance of the heater, R	0.084 k Ω
voltage across the heater, V	230 V
time taken for the experiment, t	300 s
initial temperature, T_0	39 $^{\circ}\text{C}$
final temperature, T_1	42 $^{\circ}\text{C}$
Mass of water, M_w	14 kg
specific heat capacity of water, C_w	4200 J/kg.K

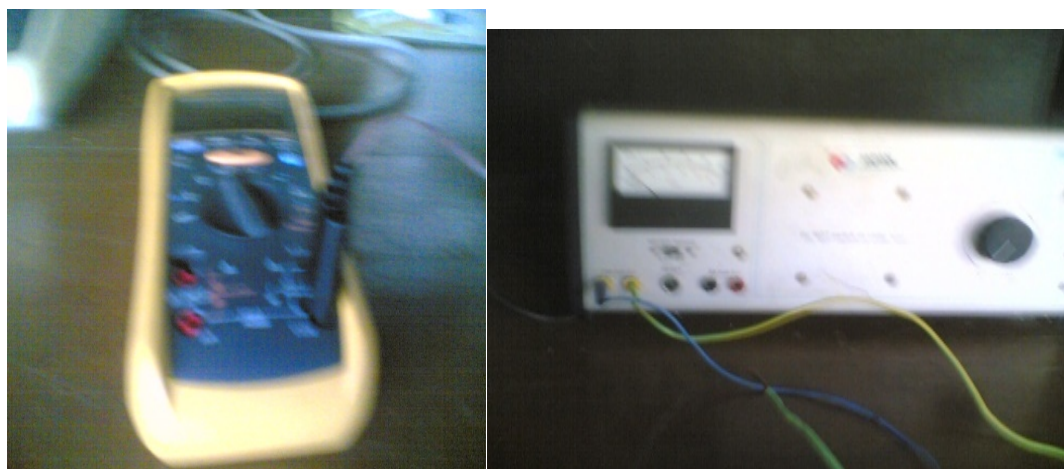
The Q value calculated using the substitutions of parameters given in Table 1 was 4176.19 J/K.

Coconut shells and husks were collected from a heap that has been discarded as waste and dried in the sun for three weeks to remove moisture. The coconut shells were then broken into pieces using a hammer, and the husks cut into pieces using a pair of scissors. This was done to help in the complete combustion process.

The sample was then placed in the brass container to make contact with the high resistance wire after which it was sealed with a silicone sealant, and the cover tightened with stainless steel screws. It was then immersed into the water bath which contained 14 kg of water. The resistance wire was checked for continuity using a multi-meter.

To check for gas leakages oxygen was circulated through the system (as shown in Figure 2). Observing gas bubbles will indicate the presence of a leakage, and therefore will require the tightening of the cover plate or the replacement of the gasket.

The temperature probe (Figure 5a) in the water bath was read to ensure that the initial equilibrium temperature had been attained and recorded as T_0 . The sample was lit by passing electric current through the copper resistance wire using the power supply shown in Figure 5b.



a. b.
Figure 5: (a) Temperature probe. (b) Power supply.

The water in the water bath was covered with polystyrene to prevent any heat losses to the surroundings. The temperature of the brass container increased and heat energy transferred to the water after ignition. A stirrer was used to ensure an equal distribution of heat in the water. The temperature probe was read periodically to monitor temperature changes that occurred. After the sample had undergone complete combustion, the final steady temperature of the water was read and recorded as T_f .

As a control to check the loss of energy, the sample was burnt in the bomb calorimeter without putting it in water and the temperature measured. The temperature of the combustion products escaping from the combustion chamber was found to be approximately equal to the temperature of the water when the process was repeated in water. This suggests that most of the energy was transferred from the brass container to the water, and, therefore indicates that heat losses were marginal.

3. Results and Discussion

3.1 Calculating the Calorific value of the shell

Data collected and used in calculating the calorific value for the coconut shell is presented in Table 2. Two different samples of coconut shell were used.

160 Table 2: Data for samples 1 and 2 for the coconut shell

Parameter	Sample 1	Sample 2
Initial mass of sample (kg)	0.050	0.050
Mass of sample after combustion (kg)	0.009	0.004
Mass of sample burnt M_b (kg)	0.041	0.046
Mass of water (kg)	14	14
Initial temperature ($^{\circ}\text{C}$)	28.3	27.2
Final temperature ($^{\circ}\text{C}$)	39.1	40.5
Temperature difference ($^{\circ}\text{C}$)	10.8	13.3

161

162

163 The calorific values were calculated as follows:

164 For sample 1 using equation (2):

165
$$Q_C = [(14 \times 4200) + (4176.19)] \times (10.8)$$

166
$$\text{Calorific value} = Q_C / M_b$$

167
$$= 680142.852 / 0.041$$

168
$$= 16588850.05 \text{ J/kg}$$

169
$$\text{Calorific value} = 16.6 \times 10^6 \text{ J/kg}$$

170
$$\text{Calorific value} \approx 16.59 \text{ MJ/kg}$$

171

172 For sample 2 using equation (2):

173
$$Q_C = [(14 \times 4200) + (4176.19)] \times (13.3)$$

174
$$Q_C = 837583.327 \text{ J}$$

175
$$Q_C = 8.4 \times 10^5 \text{ J}$$

176
$$\text{Calorific value} = Q_C / M_b$$

177
$$= 837583.327 \text{ J} / 0.046 \text{ kg}$$

178
$$= 18208333.196 \text{ J/kg}$$

179
$$\text{Calorific value} \approx 18.21 \text{ MJ/Kg}$$

180 The average calorific value of the shells using the two samples was approximately 17.40 MJ/kg.

Two different masses of the shell were burnt during combustion. A calorific value of 16.59 MJ/kg was obtained for a mass M_b of 0.041 kg burnt, while a calorific value of 18.21 MJ/kg was obtained for a mass of 0.046 kg burnt. An average calorific value of 17.4 MJ/kg was therefore obtained for the two samples. This value is greater than that for wood which is estimated to be 15 MJ/kg (Zemansky, 1957). This suggests that the shell can be used in place of wood to generate energy and dry agricultural produce. Such a substitution, if implemented, will greatly reduce the current demand on wood as fuel, thereby preventing deforestation.

3.2. Calculating the Calorific value of husk

Data collected and used in calculating the calorific value for the coconut husk is presented in Table 3. Two different samples of coconut husk were used.

Table 3: Data for samples 1 and 2 for the coconut husk

Parameter	Sample 1	Sample 2
Initial mass of sample (kg)	0.050	0.050
Mass of sample after combustion (kg)	0.000	0.000
Mass of sample burnt M_b (kg)	0.050	0.050
Mass of water (kg)	14	14
Initial temperature ($^{\circ}\text{C}$)	27.0	27.5
Final temperature ($^{\circ}\text{C}$)	35.2	35.2
Temperature difference ($^{\circ}\text{C}$)	8.2	7.7

The calorific values were calculated as follows:

For sample 1 using equation (2):

$$Q_C = [(14 \times 4200) + (4176.19)] \times (8.2)$$

$$Q_C = 516,404.758 \text{ J}$$

$$\text{Calorific value} = Q_C / M_b$$

202 $= 516,404.758 / 0.050$

203 Calorific value = 10,328,095.16 J/kg

204 $\approx 10.33 \text{ MJ/Kg}$

205

206 For sample 2 using equation (2):

207 $Q_C = [(14 \times 4200) + (4176.19)] \times (7.7)$

208 $Q_C = 484916.663 \text{ J}$

209 Calorific value = Q_C / M_b

210 $= 484916.663 / 0.050$

211 $= 9698333.26 \text{ J/kg}$

212 Calorific value $\approx 9.70 \text{ MJ/kg}$

213 The average calorific value of the husk using the two samples was approximately 10.01 MJ/kg.

214

215 For the same mass of 0.05 kg, calorific values of 10.33 MJ/kg and 9.70 MJ/kg were obtained for the two husk
216 samples. An average calorific value of 10.01 MJ/kg was therefore obtained for the two samples.

217

218 Looking at the average calorific values obtained it will be realized that the calorific value of the husk is a fraction
219 (42.5%) of that for the shell. This result is as expected as the shells are harder and denser than the husks, which are
220 fibrous and weigh less, and therefore take a shorter time to burn. This however, does not make the husk useless as
221 fuel. On the contrary, the ease with which the husk burns allows it to be used in a less energy intensive application
222 like cooking.

223

224 These obtained results are indeed lower than the real calorific values of the fuels measured due to losses inherent in
225 the measuring apparatus. These calorific values are also approximate because oxygen was allowed to flow into the
226 combustion chamber, and the combustion gases allowed to flow out. Most of the heat energy was however
227 transferred to the water using the heat-loss tube.

228

229 **4. Conclusions**

The calorific values of coconut shell and husk have been estimated to be approximately 17.40 MJ/kg and 10.01 MJ/kg respectively. With an estimated calorific value of 15 MJ/kg for wood, the value obtained for coconut shell exceeds that for wood. This suggests that coconut shells can be used in place of firewood for energy generation and crop drying. The value for the husk is lower but could be used as fuel for less energy intensive purposes.

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