Journal of Materials Science Research and Reviews

2(1): 67-73, 2019; Article no.JMSRR.45639

Determination of Calorific Values of Coconut Shells and Coconut Husks

George Amoako[1*] and Patrick Mensah-Amoah[1]

[1]Department of Physics, School of Physical Science, College of Agriculture and Natural Science, University of Cape Coast, Ghana.

Authors' contributions

This work was carried out in collaboration between both authors. Author GA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors GA and PMA managed the analyses of the study. Author GA managed the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JMSRR/2019/45639
Editor(s):
(1) Dr. Madogni Vianou Irenee, Departement de Physique, Laboratoire de Physique du Rayonnement LPR, Cotonou, Universite d'Abomey-Calavi (UAC), Benin.
Reviewers:
(1) Muhammad Raziq Rahimi Kooh, University Brunei Darussalam, Brunei.
(2) F. J. Owuna, Usmanu Danfodiyo University, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/27963

Original Research Article

Received 24 September 2018
Accepted 07 December 2018
Published 24 December 2018

ABSTRACT

The coconut palm has a lot of uses including its use as composites and as fuels. In this work, we explored the use of a bomb calorimeter to determine the calorific values of coconut shells and coconut husks. A fixed sample mass of 0.05 kg has been used for both the shells and husks and burned in a bomb calorimeter for a duration of 5 minutes. Different masses got burnt and the amount of heat transferred to the water in which the calorimeter has been immersed determined. The mean calorific value obtained for the shells, 17.40 MJ/kg, was comparable to certain wood species and that for the husks was 10.01 MJ/Kg. Such high calorific values mean that these materials, which are normally considered as waste in Ghana, 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 shells; coconut husks; calorific value; bomb calorimeter.

**Corresponding author: Email: gamoako@ucc.edu.gh;*

1. INTRODUCTION

Coconut thrives on sandy soils and is highly tolerant of salinity. It prefers areas with abundant sunlight and regular rainfall annually [1]. The coconut meat is used to produce oil. 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 [2].

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 [3,4], its application in enhancing engine performance and study of the emissions and combustion and evaluation characteristics of coconut biodiesel in diesel engines [5,6]. 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 [7].

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 materials. In most parts of southern Ghana this poses a waste disposal problem as heaps can be found littered everywhere.

Various studies have been conducted to determine the calorific values of varied wood species and combustible gases in coconut and groundnut shells [8,9,10,11]. In Ghana, the commercial production of charcoal from 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 (Southern Ghana) 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 [12].

A large proportion of energy used domestically in Ghana comes from firewood and charcoal from wood sources [13]. Such energy sources are not cheap and besides, their extensive use encourages deforestation. Energy issues have come to the forefront of national and worldwide policy makers due to 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 husks as a first step in determining their suitability as alternative fuel sources for industrial and domestic use which could encourage people to use coconut shells and husks as fuel instead of wood.

2. THEORY

The heat content, also known as 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 temperatures 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:

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

$$Q_c = \left(M_w C_w + Q\right)\left(T_1 - T_2\right) \tag{2}$$

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_cC_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 energy value Q determined using equation (4). The value of Q was calculated using the substitutions of parameters given in Table 1.

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

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

Table 1. Values of parameters substituted in calculating the energy value Q

Parameter	Value
Resistance of the heater, *R*	0.084 kΩ
Voltage across the heater, *V*	230 V
Time taken for the experiment, *t*	300 s
Initial temperature, T_0	39°C
Final temperature, T_1	42°C
Mass of water, M_w	14 kg
Specific heat capacity of water, C_w	4200 J/kg.K

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

3. MATERIALS AND METHODS

A bomb calorimeter (calibrated using benzoic acid tablets) was used to determine the energy contained in the samples by quantifying the heat generated during its combustion. Any heat exchange between the bomb calorimeter and the external environment was prevented by insulation. In preparing the samples for the experiment, the already dried coconut shells and husks were collected from a heap that had been discarded as waste. The samples were air-dried in the sun for three weeks to remove moisture. The coconut shells were broken into micrometer pieces with a hammer and the husks cut into micrometer pieces using a pair of scissors. This was done to help in the combustion process. A sample mass of 0.05 kg was used for both the coconut shells and husks and burned in the bomb calorimeter for 5 minutes. The bomb calorimeter with the sample was then immersed into the water bath which contained 14 kg of water. The resistance wire was checked for continuity using a multi-meter.

The sample in the combustion chamber was ignited (by passing a 1 A current through a 1 mm diameter chromium/nickel resistance wire), after which the power source was shut off. Complete combustion of the fuel (sample) was achieved by passing gaseous oxygen (very little of the oxygen was used intermittently so as not to interfere with the measurements) 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 (Fig. 1) was opened at one end where the sample was passed and then sealed with stainless steel 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.

Fig. 1. Bomb calorimeter (calibrated using benzoic acid tablet) with resistance wire before being sealed

To check for gas leakages oxygen was circulated through the system. 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 in the water bath was read to ensure that the initial equilibrium temperature had been attained and recorded as T_0. 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_1.

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.

4. RESULTS AND DISCUSSION

4.1 The Calorific Value of the Shell

Data collected and used in calculating the calorific value for the coconut shells are presented in Table 2. This procedure was repeated using two different samples of coconut shells.

Equation 2 was used to calculate the energy generated from which the average calorific value was determined. As provided in Table 2, different masses of the shells were burnt during the combustion, yielding different calorific values of 16.59 MJ/kg and 18.21 MJ/kg for the repeated study. This translates to an average calorific value of 17.4 MJ/kg which is comparable to the calorific values of some wood species [8,9,14]. 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.

4.2 The Calorific Value of Husks

Data collected and used in calculating the calorific value for the coconut husks are presented in Table 3. This procedure was repeated using two different samples of coconut husks.

Equation 2 was used to calculate the energy generated from which the average calorific value was determined. As shown in Table 3, for the same mass of 0.05 kg, all the samples were completely burnt, but yielded different calorific values of 10.33 MJ/kg and 9.70 MJ/kg for the repeated study. This gives an average calorific value of 10.01 MJ/kg.

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

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

Table 2. Data for samples 1 and 2 for the coconut shells

Parameter	Sample 1	Sample 2
Mass of sample after combustion (kg)	0.009	0.004
Mass of sample burnt M_b (kg)	0.041	0.046
Initial temperature (°C)	28.300	27.200
Final temperature (°C)	39.100	40.500
Temperature difference (°C)	10.800	13.300
Calorific value (MJ/kg)	16.590	18.210
Standard deviation	0.570	0.570

Table 3. Data for samples 1 and 2 for the coconut husks

Parameter	Sample 1	Sample 2
Mass of sample after combustion (kg)	0.000	0.000
Mass of sample burnt M_b (kg)	0.050	0.050
Initial temperature (°C)	27.000	27.500
Final temperature (°C)	35.200	35.200
Temperature difference (°C)	8.200	7.700
Calorific value (MJ/kg)	10.330	9.700
Standard deviation	0.230	0.220

5. CONCLUSIONS

The calorific values of coconut shells and husks have been estimated to be approximately 17.40 MJ/kg and 10.01 MJ/kg respectively. Compared with the calorific values of some wood species stated earlier, the value obtained for coconut shells compares favorably with these wood species. This suggests that coconut shells can be used in place of firewood for energy generation and crop drying. The value for the husks is lower but could be used as fuel for less energy intensive purposes. This will go a long way to ease pressure on traditional energy sources like wood, thereby preventing deforestation.

ACKNOWLEDGEMENT

We acknowledge the invaluable contributions of Dr. S. S. Sackey of the Department of Physics, University of Cape Coast. He spent a lot of his valuable time to read through the work and made a lot of corrections.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Coconut. (n.d.). Available:http://www.wikipedia.org/wiki/coconut
2. Sonntag RE, Van Wylen GJ. Introduction to thermodynamics: Classical and statistical. John Wiley & Sons, Inc., New York. 1971;453.
3. Ali M. Coconut fibre: A versatile material and its applications in engineering. Journal of Civil Engineering and Construction Technology. 2011;2(9):189-197.
4. Amoako G, Mensah-Amoah P, Sam F, Sackey SS. Some mechanical properties of coconut fiber reinforced polyethylene composite to control environmental waste in Ghana. Energy and Environment Research. 2018;8(1):1–9.
5. How HG, Masjuki HH, Kalam MA, Teoh YH. An investigation of the engine performance, emissions and combustion characteristics of coconut biodiesel in a high-pressure common-rail diesel engine. Energy. 2014;69:749-59.
6. Kalam MA, Husnawan M, Masjuki HH. Exhaust emission and combustion evaluation of coconut oil-powered indirect injection diesel engine. Renewable Energy. 2003;28:2405–2415.
7. Suzanne R. Different Uses for a Coconut. Owlcation; 2018. Available:https://www.google.com/search?ei=h34GXKXRGbyE1fAPgbqVsAE&q=uses+of+coconut+roots&oq=uses+of+coconut+roots&gs_l=psy-b.12..0.3102317.3102317..3104027...0.0..0.639.639.5-1......0....1j2..gws-wiz.xDUr5w_4BnI
8. Zemansky Waldo. Heat and thermodynamics, 4th Edition. McGraw-Hill. 1957;358-359.
9. Guenther B, Gebauer K, Barkowski R, Rosenthal M, Bues CT. Calorific value of selected wood species and wood products. European Journal of Wood and Wood Products. 2012;70(5):S. 755–757.
10. Sivakumar K, Krishna Mohan N. Performance analysis of downdraft gasifier for agriwaste biomass materials. Indian Journal of Science and Technology. 2010; 3(1).
11. Yerizam M, Faizal M, Marsi Novia. Characteristics of composite rice straw and coconut shell as biomass energy resources (Briquette) (Case study: Muara Telang Village, Banyuasin of South Sumatra). International Journal on Advanced Science Engineering Information Technology. 2013;3(3):42–48.
12. Environmental and Energy Study Institute. (n.d.). Bioenergy (Biofuels and Biomass). Available:https://www.eesi.org/topics/bioenergy-biofuels-biomass/description
13. Jones E, Childers R. Contemporary College Physics, 3rd Edition. McGraw-Hill. 2001;245-248.
14. Owens E, Cooley S. Calorific value of Irish woodfuels; 2013. Available:http://www.coford.ie/media/coford/content/publications/projectreports/cofordconnects/Calorific%20value%20of%20Irish%20woodfuels..pdf

APPENDIX

Calculating the Calorific value of the shells

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

The calorific values were calculated as follows:

For sample 1 using equation (2):

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

Calorific value = Q_C / M_b

= 680142.852 / 0.041

= 16588850.05 J/kg

Calorific value = 16.6×10^6 J/kg

Calorific value ≈ 16.59 MJ/kg

For sample 2 using equation (2):

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

Q_C = 837583.327 J

$Q_C = 8.4 \times 10^5$ J

Calorific value = Q_C / M_b

= 837583.327J / 0.046 kg

= 18208333.196J/kg

Calorific value ≈ 18.21 MJ/Kg

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

Calculating the Calorific value of husks

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

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 J

Calorific value = Q_C / M_b

= 516,404.758 / 0.050

Calorific value = 10,328,095.16 J/kg

≈ 10.33 MJ/Kg

For sample 2 using equation (2):

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

$Q_C = 484916.663$ J

Calorific value = Q_C / M_b

= 484916.663 / 0.050

= 9698333.26 J/kg

Calorific value ≈ 9.70 MJ/kg

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

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/27963