

Biomass energy potential of coconut varieties in Guyana

Bibi Nariefa Abraham^{1,*} and Oudho Homenauth¹

¹National Agricultural Research and Extension Institute, Agriculture Road, Mon Repos, East Coast Demerara, Guyana.

*Corresponding author, E-mails: narie_abraham@hotmail.com / nabraham@narei.gov.gy

ABSTRACT

Guyana's growing coconut industry has great potential for the generation of renewable energy using its waste materials currently discarded unsustainably. This study sought to investigate the energy potential of husks and shells of three common coconut varieties grown in Guyana. In this experiment, samples of coconut husks and shells were subjected to proximate, ultimate and calorific analyses. These analyses indicated that the energy value of the husks and shells of tall and dwarf coconuts were high, confirming the findings presented in previous studies. It was found that coconut shells have a higher energy content as opposed to the husk, mainly due to the presence of lignin and cellulose and a lower moisture content. The shell of one of the dwarf varieties (firmer and thinner) produced the greatest energy output. The coconut husks, however, followed closely where the tall variety reported the greatest energy value. Based on the energy output of the waste materials, possible energy, power, carbon, diesel and price savings were determined, if energy conversion is to be implemented. The analyses show substantial benefits for the country with respect to waste management, carbon emissions and costs, indicating the need for energy generation from coconut waste. A proposed gasification-pyrolysis system was developed and provided a baseline for the use of coconut biomass for energy generation in Guyana.

Key words: coconut biomass, energy content, energy generation.

INTRODUCTION

Agricultural biomass is a renewable and low emission energy source, since it contains high amounts of organic constituents and has a high energy value. Given to its structural components and characteristics, agricultural waste has been recognized as a potential source of clean energy based on benefits of both energy recovery and environmental protection. In Guyana, agricultural biomasses, more specifically coconut waste (shell and husk), are abundant and discarded inappropriately, resulting in environmental pollution and social issues (Hoque and Bhattacharya 2001). Coconut (*Cocos nucifera*) stemming from the family of *Arecaceae* (*palmae*) thrives well in areas with altitudes lower than 1000meters (m) and around coastal regions with temperatures of 23-34°C (Becker et al., 2016). The plant, usually grouped as tall and dwarf palms, produces the coconut fruit which consists of three layers; exocarp (outer skin), mesocarp (husky fibers) and endocarp (hard brown shell). The dwarf palm flowers much earlier than the tall palms, grows about 8-10m and produces coconut for 30-40 years. The tall palm can reach heights of 20-30m and produces coconuts for approximately 60-70 years and more. The waste material consists of rigid structures of polymers including lignin, cellulose and hemicellulose.

The lignin present in plant cells comprises phenolic polymers which contributes to the sturdiness of the cell wall and supports the transport of nutrients. Cellulose is a polysaccharide containing D-glucopyranose units. The hemicellulose, however, is a heteropolysaccharide structure which contains more than one type of monomer. According to Becker et al. (2016), coconut fibers contain approximately 36-43% cellulose, 0.15-0.25% hemicellulose and 41-45% lignin. The coconut shell, however, is a uniformly dense material consisting mainly of lignin and cellulose (Raghavan 2010). Tsai et al. (2006) reported that the structural components of agricultural waste, specifically lignin, cellulose and hemicellulose, allows for favorable energy generation and conversions. Coconut waste usually burnt openly or discarded unsustainably releases large amounts of carbon dioxide (CO₂) and methane (CH₄). However, this type of biomass possesses a high calorific value making it ideal for energy generation. Becker et al. (2016) reported that coconut shells

have high carbon content and a calorific value of 20.8 MJ/kg. They can therefore be used for heat and steam production. Like the shells, the coconut husk also has a high calorific value (18.62 MJ/kg), mainly due to its high concentration of lignin and cellulose, in addition to the possibility of being used for power generation.

The cultivation of coconut has increased significantly over the years, with a reported global annual level of 59.6 billion nuts in 2005. The increased production levels of the crop resulted in greater quantities of waste and in 2005; 106,100 kilotons of coconut biomass were produced, of which 60% remained unprocessed and unused (Raghavan 2010). In Guyana, coconut production has been increasing steadily, with the New Guyana Corporation (Ministry of Agriculture 2018) reporting a 29% increase in coconut and coconut-based product exports since 2016. It has also been noted that the export of coconut water has seen a 289% increase since 2016. At that the time, 56 tons of coconut water in its shell form were exported to St Kitts, Trinidad, Antigua and other countries. The increasing cultivation, processing and export of coconut-based products indicate the need for research and implementation of waste management technologies in Guyana.

The use of coconut biomass as an energy source has been studied by many researchers. However, very little work has been presented in Guyana. This study seeks to contribute to the literature by investigating and assessing the potential of the coconut types grown locally. The general aim of this study is to determine the energy characteristics and potential of the biomass of tall and dwarf coconut varieties cultivated in Guyana.

MATERIAL AND METHODOS

Experimental design

The coconut biomass for each coconut type evaluated (dwarf palm 1, dwarf palm 2 and tall palm) were sourced. The shell and husk were separated for each sample and left to sun-dry for one week. The samples were then grated and ground into small particles and sieved using a 250- micron sieve. Each sample was then sent to the Guyana Sugar Corporation (GUYSUCO) laboratory for proximate and ultimate analyses. The proximate analyses included fixed carbon, volatile matter, ash and moisture content, whereas the ultimate analyses comprised of sulphur and nitrogen content. The methods used for the laboratory analyses of the coconut samples are displayed in the table below.

Table 1. Analytical methods used in the laboratory testing of the samples.

Symb.	Name	Unit	Analytical method
H ₂ O	Moisture content	%	Soil sampling and methods of analysis (Carter 1993)
N	Nitrogen	%	ASTM D7582
Proteins	Proteins	%	
Fats	Fats	%	
Carbs.	Carbohydrates	%	
SO ₄	Sulphates	%	ASTM D7582
FC	Fixed carbon content		ASTM D7582
VC	Volatile matter	%	ASTM D7582
Ash	Ash content	%	ASTM D7582
CV	Calorific value	MJ/kg	ASTM D2015

ASTM: American Society for Testing and Materials

Samples of each treatment were also transferred to the Institute of Applied Science and Technology (IAST) for calorific analysis. The calorific analysis was conducted using a bomb calorimeter in accordance with the ASTM D2015 specifications. Ten grams of each sample were compressed and placed in a crucible. A sample was placed in the bomb vessel, after which was then filled with 30 bars of pure oxygen. The vessel was transferred to the calorimeter and after the sample was ignited. Temperature sensors within the system records the temperature variations and subsequently calculates the calorific value. This experiment was repeated for the remaining five samples of coconut biomass.

Analytical Techniques

The proximate, ultimate and calorific analyses of the coconut biomasses were compared with the findings presented in the literature. The average weight of each coconut type was recorded and the contributions of weight from the husk and shell were calculated, based on the findings presented by Raghavan (2010). Figure 1 below represents the percentage of weight contributions by the various components of a coconut used to derive the energy value of each coconut type based on the shell and husk.

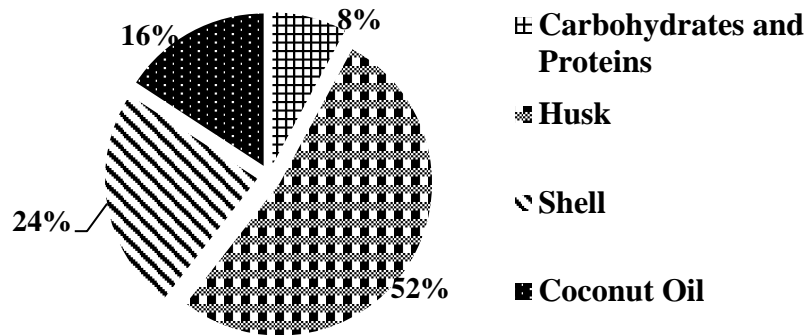


Figure 1. Pie chart of the weight percentages of the components of a coconut (Raghavan 2010).

Additionally, data regarding export levels of coconut for Guyana were sourced. The export data was then used to determine the number of dry coconuts exported yearly, and further calculate the available waste material. The energy potential of the yearly waste levels were calculated along with possible power, diesel, carbon and cost savings. The conversions of calorific value in megajoules (MJ) of the coconut waste to power in megawatt hours (MWh), diesel, carbon and cost savings were conducted using the conversion values shown in Table 2.

Table 2. Conversion values used in analysis.

Parameter	Conversion	Reference
1MWh	3600 MJ	
Diesel Savings	0.3 litres/kWh	Raghavan (2010)
Carbon Savings	2.7 kgCO ₂ /l of Diesel	
Average Diesel Prices	1 US\$ per litre	Global Petrol Prices (2018)

RESULTS AND DISCUSSION

An analysis of variance (ANOVA) test was conducted on the energy content (MJ/kg) of the coconut samples and the results are presented in figure 2. The variance of the energy values of the coconut shells and husks was calculated to be 1.14 which indicates small differences in the calorific values of the samples.

Energy analyses of the coconut biomass

The energy characteristics of the husks and shells of three coconut varieties in Guyana were analysed to determine the potential of coconut waste for energy conversion. Proximate, ultimate and calorific analyses of each coconut type (dwarf (18month and 3yr) and tall (5yr)) were done. The results are presented in the Table 3 along with findings of previous studies presented in the literature.

A: 18month coconut

B: 3yr coconut

C: 5yr coconut

In Table 3, it can be seen that coconut shells have a lower water content as compared to the husk of each coconut type and comparable to that reported in previous studies. Some notable observations are the volatile matter, ash and fixed carbon content of the samples. For both husk and shell, the dwarf variety (3yr) indicated the greatest levels of volatile matter, whereas the tall variety (5yr) reported the highest ash content. A higher level of volatile matter infers better ignition of the biomass and is therefore favourable for gasification. For the fixed carbon, the dwarf variety (18month) produced the greatest level as compared to the other varieties. This indicates that the dwarf variety would produce a longer burning time during gasification. The recorded values for ash content found in this study were greater than the results presented in the literature. Ash content is a critical consideration during gasification/pyrolysis of biomass as it can lead to fouling and other equipment issues. The ultimate analyses in this study revealed similar levels of sulphur for each coconut biomass, which were far less than that reported by Jekayinfa and Omisakin (2005). The nitrogen content, however, varied and the coconut husks indicated greater levels as compared to the shells with the tall variety (5yr) as the highest. Lower levels of sulphur and nitrogen of coconut biomass as compared to coal results in reduced environmental pollution.

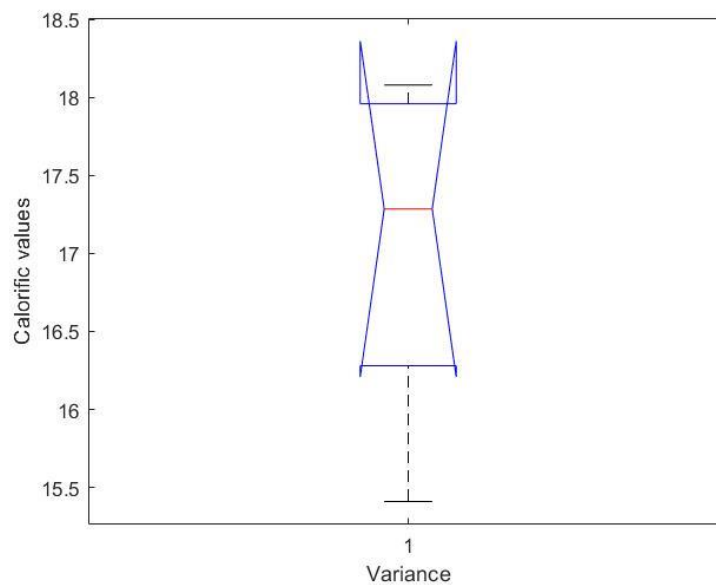


Figure 2. ANOVA of the calorific content of the samples.

Table 3. Energy characteristics of the coconut biomass studied compared to findings in literature.

Parameter	This study						Hogue and Bhattacharya(2001) (Shell)	Jekayinfa and Omisakin (2005) (Shell)	Pestano and Hose (2016) (Husk)
	A Shell	B Shell	C Shell	A Husk	B Husk	C Husk			
<i>Proximate Analysis (wt%)</i>									
Moisture Content	10.30	10.00	10.00	12.40	14.10	15.20	10.46	12.22	---
Volatile Matter	78.70	86.50	75.70	73.70	77.70	73.60	67.67	71.51	---
Ash Content	6.25	3.16	18.10	13.70	11.80	17.90	3.58	3.47	---
Fixed Carbon	15.10	10.30	6.20	12.60	10.50	8.50	18.29	8.78	---
<i>Ultimate Analysis (wt%)</i>									
Sulphur	0.04	0.04	0.04	0.05	0.04	0.05	---	3.96	---
Nitrogen	0.43	0.47	0.44	1.40	1.64	1.69	---	1.14	---
Calorific Value (MJ/kg)	17.76	18.08	17.96	16.28	15.41	16.81	18.32	19.03	16.69

A major parameter in this research was the calorific analysis of each coconut biomass. The results confirm the findings in the literature, where the coconut shell has been reported to have a high energy value as opposed to the husk. This difference in energy potential is due to the composition of the shell, that is, lignin

and cellulose, as well as other contributing factors such as water content. The calorific analyses also indicate that the shell of the dwarf variety (3yr) has the greatest energy potential as compared to the other two varieties. Visual observations of the coconut shells indicated that the shell of the dwarf coconut (3yr) is thinner and firmer than the other dwarf and tall coconuts. For the coconut husks, the tall variety (5yr) reported the highest energy value, whereas the dwarf variety (3yr) was found to have the least potential. Observations of the coconut husks indicated that the tall palm (5yr) produced thicker husks with more fibers as compared to the other varieties. The high energy value of the coconut husks can also be attributed to the presence of lignin and cellulose. In general, the calorific analyses showed that the coconut varieties in Guyana have similar relatively high energy potentials and should be used for energy conversion purposes.

In order to evaluate the potential of the coconut varieties to be used for energy generation, a comprehensive analysis was conducted. Table 4 contains the average weight of each coconut type studied in this research.

Table 4. Average weight of each coconut type studied.

Coconut type	Average weight (kg)
A	0.742
B	0.73
C	1.20

The average weight of each coconut type was then used to determine the composition, energy contribution and total energy output of the husk and shells as shown in Table 5.

Table 5. Energy potential of each coconut type studied.

Component	Composition (kg)	Energy (MJ/kg)	Energy (MJ)	Percentage of Total Energy (%)	
Shell	A	0.18	17.76	3.12	32.93
	B	0.17	18.08	3.13	34.56
	C	0.28	17.96	5.10	32.47
Husk	A	0.39	16.28	6.36	67.07
	B	0.38	15.41	5.92	65.44
	C	0.63	16.81	10.61	67.53
Total	A	0.57		9.48	
	B	0.56		9.05	
	C	0.92		15.72	

This table shows that husk of each coconut contributes to higher level of the energy output due to the higher composition. Moreover, as seen in Table 4, the tall palm (5yr) produces coconuts with a higher average weight as compared to the other two varieties, which contributed to a greater energy output. The percentage of energy contribution of the husk and shells for each coconut variety, however, is quite similar to that presented in the table above. Given the results in Table 5, the average energy potential of a typical coconut in Guyana was found to be 11.41MJ.

The export of dry coconuts from Guyana has increased significantly since 2009, with slight fluctuations from 2010 to 2015. This high export rate of coconuts has led to increased concerns related to coconut husk disposal and management. The processing of coconuts for export includes the removal of the husks, most often discarded unsustainably. In a study conducted in Brazil, it was found that 125 units of coconut material occupies 1m³ volume, which has led to land management and landfill issues (Becker et al., 2016). This study found that the average energy potential of the husk of a single coconut was 7.63MJ. To further understand and evaluate the potential of coconut waste for energy generation in Guyana, the calculated average energy value of the husk was used to determine the possible energy, power, diesel, CO₂ and price savings for the years 2009-2015 for Guyana. The findings are presented in Table 6.

Table 6. Potential energy, power, CO₂, diesel and price savings of past years from using coconut waste in Guyana.

	2009	2010	2011	2012	2013	2014	2015
Export Volume of Dry Coconuts (Tonnes)	2706.89	5448.57	7882.99	8630.27	10213.36	11165.17	8092.94
Number of Dry Coconut Nuts	3041452.81	6121993.26	8857294.28	9696928.09	11475685.39	12545134.83	9093191.01
Average Total Energy (MJ)	23209781.11	46717845.85	67591336.87	73998708.03	87572670.95	95733799.51	69391500.12
Potential Power (MWh)	6447.16	12977.18	18775.37	20555.20	24325.74	26592.72	19275.42
Projected Diesel Savings (Litres)	1934148.43	3893153.82	5632611.41	6166559.00	7297722.58	7977816.63	5782625.01
Projected CO ₂ Savings (kg)	5222200.75	10511515.32	15208050.8	16649709.31	19703850.96	21540104.89	15613087.53
Projected Price Savings (US\$)	1934148.426	3893153.821	5632611.406	6166559.002	7297722.579	7977816.626	5782625.01

This table indicates that energy, carbon emissions and price savings would be substantial if energy conversion of Guyana's coconut waste is to be implemented. The potential energy generation (MJ) was calculated based on the number of dry coconuts exported per year. The possible power output was calculated based on the energy potentials, which was then substituted for diesel-powered systems. Carbon dioxide emission savings from diesel systems were then analyzed, based on the assumption that the units were fueled by the coconut waste derived power. The CO₂ and price savings indicate the potential of coconut waste for energy generation, supporting a sustainable waste management for the coconut industry in Guyana.

CONCLUSIONS

Over the years, there have been serious concerns about the environmental pollutants emerging from non-renewable sources of energy. As such, the use of energy from biomass has gained enormous attention given to its many social, economic and environmental benefits. Some of these biomasses are usually wastes available in abundance and are discarded inappropriately resulting in environmental pollution. Agricultural biomass represents a renewable, low emission energy resource since it contains large quantities of organic constituents and has a high energy value. Therefore, it can be recognized as a potential source of renewable energy based on benefits of energy recovery and environmental protection. In Guyana, the coconut industry has gained much attention in recent years owing to its many benefits, which, as a consequence, has boosted its demand in the international market. This increased cultivation has led to the various issues related to coconut waste disposal and management. This still remains as a major challenge for the industry. Coconut waste consists of the husks and shells, materials which possess favorable energy contents. Therefore, this study was aimed at assessing the energy parameters of the biomass of three common coconut varieties in Guyana, two dwarfs (18months and 3 years) and one tall (5 years).

This study found that the energy potential of the shell is slightly higher than that of the husk, mainly due to the biomass composition. However, biomasses usually produce similar energy values which confirmed the findings in the literature. The dwarf variety (3year) indicated the greatest energy output for the coconut shell samples, while the tall palm (5year) produced the highest calorific value for the shells. The difference in the structure of the shells and husks of the coconut palm varieties may have contributed to these findings, given that the shell of the dwarf variety was thinner and firmer and the husk of the tall palm was thicker. The research indicated that the application of coconut biomass in Guyana can result in significant benefits related to price, carbon dioxide and diesel savings. The abundance of waste, its energy

characteristics and disposal challenges indicate the urge for waste management techniques.

REFERENCES

- Becker R, Quelroz TN, Santos F, Pereira MCT, Bohrer R, Dullus J, Vllares M and Machado G (2016) Productivity potential and coconut waste quality for biorefining. *Agronomy Science and Biotechnology* 2(1): 11-20.
- Carter MR (1993) *Soil sampling and methods of analysis*. Lewis Publishers, Boca Raton.
- Global Petrol Prices (2018). Diesel Prices. https://www.globalpetrolprices.com/diesel_prices/. Accessed 23 apr. 2019.
- Hoque MM and Bhattacharya SC (2001) Fuel characteristics of gasified coconut shell in a fluidized and spouted bed reactor. *Energy* 26(2001): 101-110.
- Jekayinfa SO and Omisakin OS (2005) The energy potentials of some agricultural wastes as local fuel materials in Nigeria. *Agriculture Engineering International: CIGR E-journal*, 7:1-10.
- Ministry of Agriculture (2018) Coconuts, Peppers, Eddoes and Limes among top exports for 2017. Ministry Administration, Guyana.
- Pestano LDB and Jose WI (2016) Production of solid fuel by torrefaction using coconut leaves as renewable biomass. *International journal of renewable energy development*, 5(3): 187-197.
- Raghavan K (2010). Biofuels from coconut. https://energypedia.info/images/f/f9/EN-Biofuels_from_Coconuts-Krishna_Raghavan.pdf. Accessed 10 set. 2019.
- Tsai WT, Lee MK and Chang YM (2006) Fast pyrolysis of rice straw, sugarcane bagasse and coconut shell in an induction-heating reactor. *Journal of analytical and applied pyrolysis* 76(1-2): 230-237.

Received: July 10, 2019.

Accepted: August 28, 2019.

Published: November 14, 2019.