A Preliminary Study of Pelletized Ecuadorian Cocoa Pod Husk for its Use as a Source of Renewable Energy

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ABSTRACT

In Ecuador, there is a constant need to pursuit energy independence, have created a new industry focused on energy generation by harnessing renewable sources. Biomass is established as the third leading source for producing electricity as the main source for the generation of thermal energy. However, the problems related to the low density of the different types of biomass and the difficulty in carrying and storing have caused the need to generate solids with higher density and stronger hardness known as pellets and briquettes. This paper develops an analysis of the possibilities of pelletizing the Ecuadorian cocoa pod husk and its use as biofuel. Several pellets configurations were proposed based on the diameter and length ratio. An experimental setup was established to crush and screen the cocoa pod husk in order to obtain less than 1.5 mm particle size. Then the pellets were made using a small scale pellet machine and finally burned in a combustion chamber for the evaluation of the energy potential by means of the high heat value and ash content. Finally, the selection of the most energy efficient pellet configuration is made taking into consideration international pellet quality standards as well. This large-scale project would represent a cost savings in the Ecuadorian industrial sector leading further to lowering smog emissions into the environment from burning fossil fuels and also it would prevent the cocoa pod husk as a focus for the spread of Phytophthora species which is a main cause of economic losses in the cocoa industry.

Keywords: Cocoa pod husk, Biofuels, Heat value, Pellet, Biomass, Renewable energy.

1. INTRODUCTION

Cocoa is a natural fruit produced in Ecuador and according to the Third Agricultural Census from the Ecuadorian Ministry of Agriculture and Livestock, 2012, 2014 cocoa production nationwide was 133,323 tons and a harvested area of 390,176 hectares. The seed is mainly used in the chocolate industry and the cocoa pod husk (CPH) is used to generate fertilizer, pectin, etc.; seeking to exploit this waste as raw material.

The development of new research over the years on the use of CPH to contribute to co-combustion or complete combustion, generating clean energy in industry and decreasing fuel consumption leads to explore possibilities of pelletizing CPH and its use as biofuel based on the contribution to combustion within the industry based on the following parameters: diameter, particle density, heat value, humidity and ash content (International Cocoa Organization, 2014).

The need to generate electric and thermal energy, global warming caused by increased emissions of greenhouse gases, the increase in prices of fossil fuels and the pursuit of energy independence, have created a new industry focused on generating energy by harnessing renewable sources. Biomass is constituted as the third main source for producing electricity as the main source for the generation of thermal energy. However, problems related to low density of different types of biomass and difficulties in transport and storage have caused the need to generate solids with higher density, hardness and stronger known as pellets (Brenes, 1990). This paper seeks to develop an analysis of the possibilities of pelletizing cocoa pod husk and its use as biofuel.

According to Sikkema et al. (2009) in their Final Report on Producers, Consumers and Traders of wood pellets, several physical and chemical parameters of pellets are listed following French standards in Table 1.

Table 1. Physical and chemical parameters for mixed biomasses according to French standards.

Parameter	Unit	Agro+	Agro
Diameter	mm	6- 8	6 -16
Length	mm	10 - 30	10 - 30
Humidity	% wt	< 11	<15
Low Heat Value	MJ/kg	> 15.5	> 14.7
Density	kg/m^3	> 650	> 650
Ash content	% wt	< 5	< 7

Source: Sikkema et al. (2009)

In previous investigation, Syamsiro et al., 2007, obtained experimental results in combustion of bio-pellets made of

Indonesian CPH showing the potential of this agricultural waste to be used as alternative fuel for combustion systems. The development of the proposed pellets and experimental evaluation of the energy potential based on their composition and further selection of the pellet configuration with the greater energy efficiency in agreement with international quality standards is the main objective of this research.

According to the above, the development of this research seeks to generate and apply technologies that support the transformation of the Ecuadorian energy grid to social and economic; and also to prevent the CPH as a focus for the spread of Phytophthora species, a pathogen that produces important economic losses in the cocoa business.

2. MATERIALS AND METHODS

This study was performed at the facilities at Guayaquil University, specifically in the Laboratory of Unit Operations at the Faculty of Chemical Engineering. The pellets manufacturing process was divided into the following stages:

Raw material collection

CPH from cocoa CCN-51 (Figure 1), a cloned cocoa type from Ecuador was collected and selected from farms located in the Guayas province, Ecuador.

Figure 1. Collected CPH CCN-51 type.

Drying

The raw material went through a pre-drying under sun light for 24 hours and also through a vapor dryer for 2 hours at a temperature of 60 °C to decrease the humidity percentage to 13 %, as seen in Figure 2.

Figure 2. Vapor dryer used at the facility.

Crushing

In order to get the appropriate size of the material for the milling stage, the CPH was crushed in a hammer mill to obtain a size of 8 mm.

Milling and screening

The CPH went through a ball mill and then screened to obtain a powder with grain size less than 1 mm, following references by Syamsiro et al. (2011) suitable for subsequent pelletizing.

Pelletizing

The material already milled and screened, was conducted to a pelletizing machine which was designed and built during this study following previous references by Soto and Núñez (2008).

Figure 3. Ball mill used at the facility.

In Figure 4 it is possible to see a screw press built to compact the material and thus obtaining pellets with dimensions according to international standards. Three different diameters of 6 mm (A), 8 mm (B), 10 mm (C) and 15 mm length were studied (Figure 5).

Figure 4. Screw press built to make the pellets.

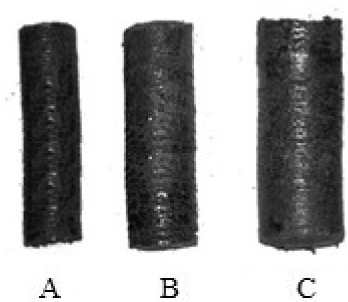

Figure 5. Samples of pellets for testing

Physical and Chemical Analysis: During this stage laboratory tests were conducted at the Laboratory of Petro chemistry at the University of Guayaquil, which is certified with ISO 17025 standard to determine friability, percentage of ash, humidity and higher calorific value of the proposed pellets configurations.

Selection: After obtaining results of laboratory tests, a thorough analysis is done to determine which of the proposed pellets configurations is in best agreement with international quality standards.

3. RESULTS AND DISCUSSION

To calculate the moisture content of the raw material, 2 samples of CPH before crushing were dried in an oven at 80 ± 5 °C for about 5 hours and then weighed. After observing no variation in the weight, the moisture content was calculated by means of Eq. 1. This yielded an average result of 13%. This was for a pellet configuration of 100% CPH.

$$MC = \frac{IW - DW}{DW} \times 100 \qquad \text{Eq. (1)}$$

where:
MC: Moisture content
DW: Dry weight
IW: Initial weight

Then, in the screw press, there were made pellets of three different diameters: 6, 8, 10 mm and length of 15 mm. As a reference data, 25 units were produced for each configuration.

In order to obtain the density of the pellets, the ratio of mass to volume was computed as shown in Table 2.

Table 2. Ratio of surface area to pellet mass for different diameters

	A (D = 6 mm)	**B (D = 8 mm)**	**C (D = 10 mm)**
Density (kg/m^3)	821.9	1098.2	1063.4

According to this, type B pellets show the highest density followed by type C and type A. However all pellets configurations are over the minimum value of 650 kg/m^3 of the standards shown in Table 1.

Friability tests were performed simultaneously after finishing a high number of pellets of each configuration using the method followed by Soto et al., 2008. This test consisted of throwing a sequence of pellets from a height of 1 m, to a ceramic floor and see how many pieces they break each. After performing the test, a ratio between the initial and the resulting pellets at the end of it is computed by means of Eq. 2.

$$FR = \frac{IE}{FE} \qquad \text{Eq. (2)}$$

where,
FR: Friability
IE: Initial amount of elements
FE: Final amount of elements

In Figure 6, it is possible to see friability results for the tested configurations.

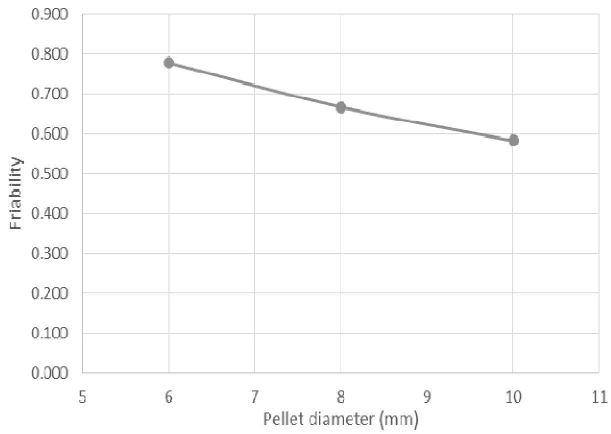

Fig. 6. Pellets friability vs. diameter.

According to this, the pellets configuration of 6 mm (A) shows the best consistency and thus more resistance to impact and to keep its shape for longer than the other tested configurations.

High heat value (HHV) tests

Results for this tests were obtained by means of an oxygen bomb calorimeter (Figure 7).

Fig 7. Oxygen bomb used for HHV tests.

CPH samples of 1 g where selected and tested in this equipment. In order to obtain the high heat value, Eq. 3 was used.

$$HHV = \frac{C_{bomb} \times \Delta T - Q_w}{m_{fuel}} \qquad \text{Eq. (3)}$$

where,
HHV: High heat value (kcal/kg)
C_{bomb}: Heat bomb capacity (kcal/°C)
ΔT: Water Temperature difference (°C)
m_{fuel}: Fuel mass (g)
Q_w: Oxidation heat of the fuse wire (kcal).

Therefore the high heat value for the CPH resulted an average of 20.2 MJ/kg. Compared to results of Higman and van der Burgt (2008) and Syamsiro et al. (2007), the HHV obtained for the CCN-51 Ecuadorian CPH tested is higher in 26.25% and 18.88% respectively.

Effect of the pellets dimension on the mass losses

In Figure 8 it is possible to observe the effect of pellet dimension on the mass losses of CPH. The pellet diameter of 10 mm produced the fastest mass loss of CPH, followed by diameter of 8 mm and finally diameter of 6 mm which produced the slowest mass loss.

According to Syamsiro et al., 2011, the ratio of surface area to pellet mass (R) is the most important parameter for combustion reaction. This parameter was computed for all of the pellets configuration and resulted in:

Table 3. Ratio of surface area to pellet mass for different diameters

	A (D = 6 mm)	**B (D = 8 mm)**	**C (D = 10 mm)**
R (cm^2/g)	9.69	5.74	5.01

According to the results in Table 3, while the ratio of surface area to pellet mass decreases, the combustion turns more efficient due to the increment of the pellet mass loss.

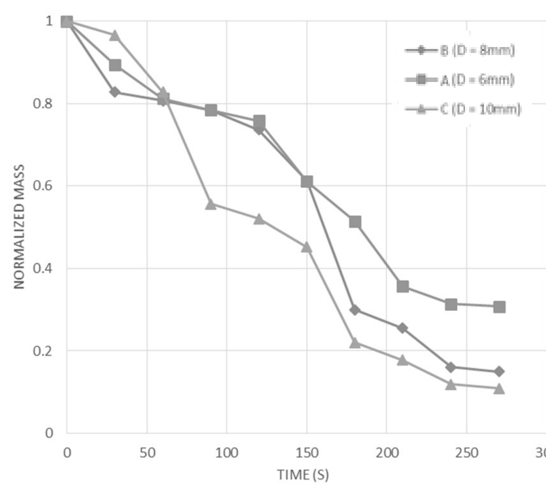

Figure 8. Normalized mass vs. time for different pellet configurations.

Ash content

Ash content in percentage was obtained using a high temperature muffle furnace at a temperature of 300 °C. The samples were weighed before and after ashing to determine the concentration of ash present. The ash content was computed using Eq. 4 and expressed on a dry basis. Results are shown in Table 4.

$$\%ash = \frac{m_{ash}}{m_{dry}} \times 100 \qquad \text{Eq. (4)}$$

where,
m_{ash}: mass of the ashed sample (kg)
m_{dry}: original mass of the dried samples (kg)

Table 4. Ash content for different pellet diameter.

	A (D = 6 mm)	B (D = 8 mm)	C (D = 10 mm)
Ash content (%wt)	30.81	10.92	10.07

It is possible to observe that since it took more time for type A pellets to burn completely, ash content was higher followed by type B and finally by type C. However, the ash content resulted higher by 3% than the maximum value for Agro pellets shown in Table 1.

4. CONCLUSION

With this investigation, it was possible to propose a method for making pellets of cocoa pod husk and in this way confirm the possibility of pelletizing this agricultural waste. In terms of friability, a composition of 100% CPH pellets shows good response and according to the high heat value, CPH has resulted a very promising biofuel compared to values from references. The study of the effect of the pellet dimension confirmed previous results of references stating that a larger surface area provides faster mass loss of the pellet. Therefore, the best pellet configuration had a diameter of 10 mm and a length of 15 mm. This results confirm the potential of the Ecuadorian CCN-51 cocoa pod husk as a biofuel and lead to propose new possibilities for clean energy use.

5. FUTURE WORK

The next step in this research will be to study the performance of CPH pellets with binder materials in terms of physical and chemical parameters for biopellets according to international standards such as heat value, friability, density, humidity and ash content.

6. ACKNOWLEDMENTS

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