Influence of the Binder on the Thermo-Mechanical Properties of Energy Briquettes Based on Cocoa Shells

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Abstract

In optics to improve thermal and mechanical properties of briquettes from cocoa pods husks, influence of adding binder was undertaken. With this intention, after having carried out preliminary tests of brickwork where three binders were tested to know the molasses of sugar cane, the gelatinized starch of manioc as well as the skins of manioc, only the starch of manioc and the molasses were selected on the basis of IRI (resistance index), of the Peak Load (PL) and Final Load (FL) of a needle on briquettes. The optimal range of the percentage of binder ratio is between 9.4\% and 12.5\%, for molasses and gelatinized starch. Thermal properties of the raw materials were studied on the basis of determination of the ash content (AC), volatile mater (VM), fixed carbon (FC) and calorific value (CV). Molasses and starch binder contributes to increase the calorific value (16.69±1.00 – 19.80±4.69 MJ/kg).

Keywords: Briquettes; energies; biomass; binders; cocoa pods husk.
1. Introduction

Energy is an essential basis for ensuring the social and economic development of a country. States must take this into account in order to guarantee populations a sufficient supply of energy while ensuring the sustainability of this supply that is to say with minimum costs and reduced effects on the environment [1]. The energy supply represents a permanent challenge especially for our African societies where the need does not cease increasing. Due to the high cost of petroleum products on the world market with, in a geopolitical context marked by a generation of insecurity in supply (their stocks and deposits are in limited quantity which has the effect of the difficulty of exploitation, 1 increase in demand and therefore in the cost of production), underdeveloped and developing countries have little access to this source of energy. Yet access to energy is essential to ensure food security and the Sustainable Development Goals. Almost one in five people worldwide do not have access to modern energy services and around three billion people depend on traditional biomass for cooking and heating [2]. In Cameroon, biomass energy covers more than 64% of energy needs [3]. In sub-Saharan Africa, this biomass is the main source of energy used in the form of wood (fuel wood and charcoal), according to the [4], 90% of this wood is taken from the forests of Africa, their excessive use presents risks of deforestation, hence the need to replace this wood with an equivalent energy source (a wood equivalent), namely energy briquettes. Briquetting is a technique used to transform biomass (of low energy content) into a denser product (more compact) using a mechanical press or an extruder [2, 5]. In addition to having the advantage of replacing wood, this technique allows the reduction of the volume of waste to be disposed of at the landfill [6, 7]. Energy briquettes can be produced from household or municipal waste, or from biodegradable agricultural and agro-industrial residues (millet, cassava, cotton stalks, rice husks, peanut shells, cane bagasse, corn cobs, cocoa shells, etc.) [8]. Cameroon generates more than 93,704.5 tonnes of cocoa dry hulls each year which have various uses ranging from outright abandonment to soap making [9], but so far under industrially valued. To date, the development of cocoa shells has also been the subject of several studies in the energy field, in particular those of [10-12]. which have respectively focused on the production of biogas, bioethanol and the production of solid fuels by briquetting. From the work of [12], it has been observed that cocoa shell briquettes have poor mechanical properties, it is in this perspective that the present work aims to study the influence of the incorporation of the binder on the thermomechanical properties of energy briquettes from cocoa shells. From the above, this work has the general objective of improving the thermal and mechanical properties of energy briquettes based on cocoa shells. More specifically, it will be a question of:

- Study the influence of particle size on the thermo mechanical properties of energy briquettes

- Study the influence of type and fraction by linking on the thermo mechanical properties of energy briquettes

With the associated hypothesis:

- Small particles help to increase the hardness of energy briquettes

- There is an optimal rate of incorporation of binder (depending on its nature) ensuring good thermomechanical properties of energy briquettes
2. Materials and Methods

The plant material consists of: cocoa shells (picture 1) which were collected from farmers in the coastal region of Cameroon, cassava roots (Manihot esculanta C.) obtained in Nkongsamba. From these cassava roots, the starch was extracted as well as the skins in order to serve as a binder and sugar cane molasses, also used as a binder and having been obtained from sugar industry.

![Cocoa shells](image1) ![Cassava husk](image2) ![Sugar cane molasses](image3)

**Figure 1:** raw material used

The mould containing the paste was then squeezed at 20MPa using a hydraulic press (EURO LABO, model 25.011).

2.1. Characterization of the raw material

The granulometry of the cocoa shell and cassava skin powders obtained after grinding was analyzed using a particle analyzer of MASTERSIZER 2000 brand. For this, the analysis was carried out on 0.5 g of powder and the solvents used are 96% ethanol and distilled water for the powders of cassava skins and cocoa shells respectively. The dry matter was carried out by the method of AFNOR (1982). Total ash is quantified by the method described by [13]. It consists of completely incinerating a sample until white ash is obtained in a muffle furnace set at 550°C. For this, the porcelain crucibles containing the samples from the oven at 105±2°C (M₂) are placed in the oven. After incineration for 24 hours, the crucibles are removed from the oven using tongs, then cooled in the atmosphere of a desiccator and weighed (M₃). Water adsorption capacity used is that described [14]: 1 g of powder (M₀) is mixed with 10 ml of distilled water, the whole is stirred for 15 minutes and then centrifuged.
at 2500 rpm for 30 minutes in a Heraeus-kendro brand centrifuge, primo biofuge model A. The pellet is weighed \((M_2)\) and dried in an oven at 105 ± 2°C for 24 hours. The mass of the dry pellet \((M_1)\) is determined. The water absorbed is calculated in apparent water absorption capacity \((CAE_a)\) and in real water absorption capacity \((CAE_r)\):

\[
CAE_a = \frac{M_2 - M_0}{M_0} \times 100
\]

\[
CAE_r = \frac{M_2 - M_0}{M_1} \times 100
\]

The amount of lignin was determined according to the standard (insoluble klasont lignins). This method consists of dissolving all of the organic matter except lignins with concentrated sulfuric acid, then diluted to the boil. Crude or insoluble fibers include cellulose, a few hemicelluloses and lignin. The crude fiber content of the samples was determined by the method of Weende [15]. This method consists in treating the sample at boiling point with sulfuric acid and then with soda. The residue obtained is dried, then incinerated and weighed. Total sugars were extracted and quantified by the phenol method (Dubois et al., 1956). Total sugars were extracted and quantified by the phenol method (Dubois et al., 1956). Total nitrogen is determined after mineralization of the samples according to the Kjeldahl method, and assay according to the colorimetric technique of [16]. Iodine \((I_2)\) interacts with amylose and amylopectin to give a blue and brown color, respectively. The spectra of the \(I_2\)-amylose and \(I_2\)-amylopectin complexes are different. As a result, these complexes have maximum wavelengths for amylose \((\lambda_{max} = 630 \text{ nm})\) and amylopectin \((\lambda_{max} = 548 \text{ nm})\) which are different. In addition, amylose absorbs in the near visible while amylopectin does not absorb there. We can therefore use this spectral difference to simultaneously measure total starch, amylose and amylopectin in biological material. In this manipulation we will consider that the absorbance at 580 nm is linked to both amylose and amylopectin and therefore to total starch. The brix degree of the molasses was measured at 23°C using a HANNA brand refractometer (HI 96801 manufactured in Romania) whose measurement ranges vary from 0 to 85% Brix. The result is the average of three measurements.

Total lipids are extracted with Soxhlet according to the Russian method described [17]. The Volatile Matter (MV) expressed in g /100g of dry matter (MS) represents the amount of organic matter of the dry residue (Dry Matter). The determination of volatile matter refers to the fraction of biomass which is released when it is incinerated at a temperature between 400 and 500 °C. During combustion, the biomass is broken down into two fractions, the gas fraction and the solid fraction [18]. The carbon content (CF) expressed in g / 100g of dry matter (MS) is obtained by the difference to 100 of the sum of the volatile matter (MV) and ash content (TC) (Vargas-Moreno et al., 2012). Calorific value (PC) represents the amount of energy contained in a unit of fuel mass. It was determined by using mathematical models based on knowledge of the ash content (TC), volatile matter (MV) and fixed carbon (CF) [18]. The briquetting was carried out according to the method described in FIG. 10 below, and according to a method similar to those of the [2, 19-21]. Indeed, the cocoa shell powder obtained after grinding was mixed manually in a porcelain mortar (in order to facilitate the incorporation of binders) with the different binders in variable proportions, then each mixture (10g) was compacted by submission at a load between 10, 15 and 20 tonnes.
2.2 Characterization of the energy briquettes produced

The volume and mass measurements were carried out on each briquette as soon as it left the mold and until mass and volume stability. The volume V of the briquettes was determined using a vernier caliper by measuring their diameter and height. The textural analysis of the energy briquettes was carried out using a Brookfield Lfra Texture Analyser 4500 penetrometer. This is the measurement of the Peak Load and the Final Load expressed in g.

To do this, a needle probe was chosen, the test consisted in making it penetrate up to a distance of 4.5 mm (approximately 56% of the thickness of the briquette) inside the briquettes with a sensitivity of 1g and a penetration speed of 1mm/s. Three repetitions were made for each briquette. La résistance de la briquette a été déterminée suivant une méthode de caractérisation décrite par Suparin [22]. Elle consiste à laisser tomber une briquette sur une masse métallique à une distance de 1,5 m ; sans vitesse initiale, et de façon répétée jusqu’à fractionnement de la briquette. Les résultats peuvent s’exprimer en Indice de Résistance à l’Impact (IRI), afin d’étudier l’effet combinée de la pression, de l’incorporation du liant et de la taille des particules sur la résistance au choc des briquettes énergétiques [22].

The study of the combustion of the briquette consisted in determining the ignition time and the total duration of combustion of the briquettes on the one hand and in establishing the temperature profile of the briquette during the combustion on the other hand.

3. Results and Discussion
3.1. Physicochemical characterization of cocoa shells, cassava skins, starch and sugar cane molasses

Table 1: below presents the physicochemical characterization of the raw material.

<table>
<thead>
<tr>
<th>content (g/100 MS)</th>
<th>Cocoa shells</th>
<th>Cassava skins</th>
<th>Cassava starch</th>
<th>Molasses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water content</td>
<td>22.35 ± 0.05bA</td>
<td>15.29 ± 0.56aB</td>
<td>19.42 ± 0.26A</td>
<td>30.79 ± 4.97aC</td>
</tr>
<tr>
<td>Ash content</td>
<td>6.05 ± 1.67aA</td>
<td>1.80 ± 0.72bB</td>
<td>/</td>
<td>9.81 ± 0.15b</td>
</tr>
<tr>
<td>Total sugar content</td>
<td>10.2 ± 0.12aA</td>
<td>41.87 ± 0.82cB</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Fat content</td>
<td>6.6 ± 1.68aA</td>
<td>13.48 ± 0.53dB</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Crude protein content</td>
<td>19.60 ± 3.46bA</td>
<td>12.33 ± 5.47eA</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Starch content</td>
<td>/</td>
<td>10.20 ± 0.80f</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Raw fiber content</td>
<td>49.33 ± 5.86e</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Cellulose content</td>
<td>36.25 ± 2.50d</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Lignin content</td>
<td>41.67 ± 2.52c</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Brix degree</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>82 ± 0.4c</td>
</tr>
</tbody>
</table>

a, b, c,…: for each column, the values affected by the same lowercase letter while exposing are not significantly different (P <0.05%).

A, B, C… for each line, the values affected by the same uppercase letter when exposing are not significantly different (P <0.05%).

Cocoa shells have a varied composition. In fact, it contains water, sugars, fat, proteins and fibers. There is a fairly large proportion of fiber with a value of 49.33 ± 5.86 g per 100g of dry matter. According to [23] the raw fibers have a value between 28.75-34.50% in cocoa dry shells while [24]. Observed a fiber content 33.74 ± 1.7%. Water content values are just as important for cocoa shell powder and cassava starch unlike cassava skins, however sugar cane molasses has the highest water content (30.79 ± 4.97). Proteins are the least represented with a content of 0.20 ± 0.03g per 100g of material dried. As for cassava skins, first place is occupied by total sugars, followed by fat and starch. Like cocoa shells, proteins are the least represented here with a content of 0.12 ± 0.05 g per 100g of dry matter. The starch prepared has a different water content (p <0.05%) than that of cassava skins. The same is true for sugar cane molasses.

The ash content has a higher value for molasses and lower for cassava skins, Roberto et al., (2012) have also observed an ash content comparable to that obtained for cocoa shells, i.e. 8, 8 ± 0.6%.

3.1.1. Rheological properties of starch

Figure 2 below shows the curves of the viscosity and temperature profile of cassava starch as a function of time. The gelatinization temperature makes it possible to indicate the minimum temperature required to cook a given sample, in this figure it is 80.65°C, it also provides information on energy costs. The viscosity peak indicates the water retention capacity of the starch and is used to indicate the viscous charge that can be obtained using a mixer cooker, in this figure, it is 6462cp. The time required to reach the gelatinization peak is 212 seconds.
Figure 2: Profile of viscosity and temperature of cassava starch as a function of time

Figure 3: Impact resistance index of energy briquettes with added starch, molasses and cassava skins
With regard to starch as well as molasses, the maximum value of IRI reached is 1000 and corresponds to a number of 10 launched without breaking the briquette. While for cassava skins, the maximum value reached is 65. Overall, the IRI values recorded for starch and molasses are higher than those for cassava skins. This difference can be explained by the amount of water incorporated, but if this amount of water becomes too large, the IRI decreases because the briquette becomes too soft and breaks easily.

The excessively large standard deviation values are due to the fact that not only does the break not take place with an equal number of throws, and even when the break takes place during the determination, the number of pieces varies from one briquette to the other for the same point and therefore the result presented is only the average of the three tests carried out. This can result in the heterogeneities inside the briquettes which make them different from each other.

According to [25], the water present in the raw material during the densification process can act naturally as a binder by creating a Wan Der Waal type bond due to the increase in the specific surface area of the particles. The percentage of water provided by the cassava skins (not related to the dry matter base) is 13.26 ± 0.56%, and therefore the mixture with cocoa shells whose water content (not related to the dry matter base) is 18.27 ± 0.03% can only help to reduce the water content and therefore the impact resistance of the energy briquettes produced.

With a view to seeing the contribution of water to the increase in mechanical strength, the test was repeated, this time incorporating 2 ml into the cocoa + cassava skin mixture (Figure 4), it was found that there is an incorporation range (12.25-25%) for which the impact resistance is maximum.

![Figure 4: Impact resistance index of energy briquettes with added cassava skins as a binder + 2ml of water](image)

[19, 20] have also reported that the maximum acceptable humidity varies, depending on the process, from 10 to 20%, although generally less than 10%.

### 3.1.2. Energy properties of the raw materials

Table 3 below presents the different energy properties of the raw materials used.
Table 3: Energy properties of raw materials

<table>
<thead>
<tr>
<th></th>
<th>TC (g/100g MS)</th>
<th>MV (g/100g MS)</th>
<th>CF (g/100g MS)</th>
<th>PC (MJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cocoa shells</td>
<td>6.05±1.67^bA</td>
<td>87.33±3.21^bcC</td>
<td>6.62±1.54^bA</td>
<td>15.91±0.03^abB</td>
</tr>
<tr>
<td>Cassava skins</td>
<td>3.35 ±0.73^aA</td>
<td>96.98±0.89^cC</td>
<td>1.25±0.16^aA</td>
<td>15.54±0.09^abB</td>
</tr>
<tr>
<td>Sugar cane molasses</td>
<td>9.81±0.15^AB</td>
<td>70.08±2.72^abcB</td>
<td>20.11±2.56^bcB</td>
<td>17.96±4.54^abB</td>
</tr>
<tr>
<td>Cocoa shells + 9.4% cane molasses</td>
<td>5.88±1.45^abA</td>
<td>72.91±8.72^abcC</td>
<td>19.90±8.23^bcB</td>
<td>19.36±1.79^abB</td>
</tr>
<tr>
<td>Cocoa shells + 12.5% cane molasses</td>
<td>4.98±2.49^AB</td>
<td>85.31±1.83^bcB</td>
<td>9.71±3.22^abC</td>
<td>16.69±1.00^dD</td>
</tr>
<tr>
<td>Cocoa shells + 9.4% starch</td>
<td>6.05±1.36^BA</td>
<td>82.63±6.90^BcC</td>
<td>11.32±5.57^AB</td>
<td>16.84±0.89^abB</td>
</tr>
<tr>
<td>Cocoa shells + 12.5% starch</td>
<td>6.05±1.37^BA</td>
<td>67.62±21.34^bB</td>
<td>26.32±22.64^AB</td>
<td>19.80±4.69^AB</td>
</tr>
</tbody>
</table>

a, b, c,…: for each column, the values affected by the same lowercase letter while exposing are not significantly different (P <0.05%).

A, B, C,… : for each line, the values affected by the same uppercase letter when exposing are not significantly different (P <0.05%).

**TC: Ash Content; MV: Volatile Matter; CF: Fixed Carbon PC: Calorific Power**

Table 4 above shows that the ash content values are not statistically significant at the 5% threshold for cocoa shells, and for cocoa shells with added binders. The incorporation of starch does not seem to influence the ash content (6.05%) on the other hand there is a decrease in the ash content with incorporation of molasses (4.98%) but not significantly. So the incorporation of molasses influences the ash content but not significantly. Vargas-Moreno et al., (2012) have also reported that the ash content can vary from less than 1% for certain wood species to more than 30% or even 40% on the basis of dry matter for lignocellulosic waste biodegradable. The percentage of volatile matter is greater for cassava skins but not statistically different from cocoa shells and cocoa shells incorporated with 12.5% molasses and 9.4% starch. Molasses has a lower volatile content than cocoa shells and cassava skins. Overall the incorporation of binder decreases the percentage of volatile matter compared to single hulls. [26] have also observed that the percentage of volatile matter in the biomass is between 48 and 86%, overall the values observed for our samples are included in these values with the exception of skins of cassava and single cocoa shells. However, the values obtained for cocoa shells are comparable to that obtained by Roberto et al., (2012), ie 69 ± 1%. [26] observed that the fixed carbon rate for all types of biomass is between 1% and 38% based on the dry matter, with regard to the table above, the rate the highest is 26.32 ± 22.64% and amounts to cocoa shells incorporated with 12.5% starch. On the other hand, we observe that the cassava skins have a low fixed carbon content, ie 1.25 ± 0.16%. Overall, cocoa shells with added binders have a higher calorific value than other raw materials, from which it can be said that the incorporation of molasses and starch contributes to increasing the calorific value of this raw material. As for cassava skins, in addition to being low in ash and fixed carbon, they
have the lowest calorific value in this table. Molasses also has a higher calorific value than that of cocoa shells without the addition of a binder. However, the values obtained for cocoa shells are comparable to that obtained by [27] namely $17.313 \pm 1$, and comparable to those obtained [17] for certain species of wood $19.07 \pm 1.22\text{MJ/kg}$.

3.1.3 Textural properties of energy briquettes

Figure 5 above present’s curves with decreasing gears as a function of the rate of incorporation of the binder as well for the molasses as for the starch and the skins of cassava. With regard to starch and molasses, the two curves seem to be identical and show that the incorporation of starch and molasses as a binder reduces the firmness of the energy briquettes with values tending towards 0, hence it is therefore necessary to find an optimal range of incorporation of binder which ensures good firmness and good impact resistance. Cassava hides, on the other hand, seem not to have such low values, but since their impact resistance is low, the experiment was repeated with the addition of 2ml of water (figure) and It appears that the addition of water drastically decreases the firmness. In this context, the addition of cassava skins as a binder does not seem to have good mechanical properties.

Textural properties of energy briquettes

Figure 5 below shows the maximum load (in grams) of needle penetration (PL) and needle withdrawal (FL) depending on the incorporation rate of the different binders.
**Figure 5:** Textural properties of energy briquettes with added cassava starch, sugar cane molasses and cassava skins.

Figure 5 above presents curves with decreasing gears as a function of the rate of incorporation of the binder as well for the molasses as for the starch and the skins of cassava. With regard to starch and molasses, the two curves seem to be identical and show that the incorporation of starch and molasses as a binder reduces the firmness of the energy briquettes with values tending towards 0, hence it is therefore necessary to find an optimal range of incorporation of binder which ensures good firmness and good impact resistance. Cassava hides, on the other hand, seem not to have such low values, but since their impact resistance is low, the experiment was repeated with the addition of 2ml of water (figure) and it appears that the addition of water drastically decreases the firmness.
In this context, the addition of cassava skins as a binder does not seem to have good mechanical properties.

![Graph showing peak and final load values](image)

**Figure 6:** Peak and Final Load of energy briquettes with cassava skins added as a binder + 2ml of water

Gelatinized starch and sugarcane molasses seem to have good mechanical properties compared to cassava skins as a binder. For the latter, there is an optimal incorporation range for which the impact resistance is maximum and having a good texture as summarized in Table 5 below.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Binder</th>
<th>Starch PL</th>
<th>Starch FL</th>
<th>Molasses PL</th>
<th>Molasses FL</th>
<th>IRI PL</th>
<th>IRI FL</th>
<th>IRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>2802</td>
<td>2801</td>
<td>41.67</td>
<td>2802</td>
<td>2801</td>
<td>41.67</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3.1</td>
<td>3554</td>
<td>3354</td>
<td>213</td>
<td>3815</td>
<td>3716</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>6.3</td>
<td>2571</td>
<td>2411</td>
<td>258</td>
<td>3511</td>
<td>3363</td>
<td>216</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>9.4</td>
<td>1886.5</td>
<td>1834.5</td>
<td>833.3</td>
<td>2919</td>
<td>2735</td>
<td>750</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>12.5</td>
<td>1717</td>
<td>1348</td>
<td>1000</td>
<td>2713</td>
<td>2198</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>25</td>
<td>310</td>
<td>263</td>
<td>833</td>
<td>567</td>
<td>474</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>37.5</td>
<td>134</td>
<td>133,5</td>
<td>125</td>
<td>189</td>
<td>165</td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>50</td>
<td>57.5</td>
<td>40</td>
<td>/</td>
<td>161</td>
<td>146</td>
<td>/</td>
<td></td>
</tr>
</tbody>
</table>

From this table, the observation made is that beyond 12.5% of binder incorporation, the values of Peak and Final Load are low which results in a weak texture and that below 9.4% and above 25%. The impact resistance is just as low, which shows that [9.4% -12.5%] is the suitable range for incorporating gelatinized starch as well as sugar cane molasses as a binder. It was a question in this preliminary study of testing the various selected binders and of fixing their optimal incorporation rates, in the light of the results obtained it should be noted that the briquettes of cocoa shell skins with added cassava skins have good textural properties but very low mechanical resistance to impact. On the other hand, for the energetic cocoa shell briquettes with added gelatinized starch or sugar cane molasses, they have an optimal incorporation area which not only allows the briquettes to resist mechanical shock but also to have good firmness, d” where the choice of the appropriate binder for the rest of the work fell on the
latter two. At the end of these preliminary studies, it was also a question of determining the thermal properties of the raw materials as well as cocoa shell powders added with 9.4% and 12.5% of gelatinized starch and cane molasses as a binder.

4. Conclusion

Arrived at the end of this work where it was a question of studying the influence of the binder on the thermomechanical properties of energy briquettes based on cocoa shells, after having carried out preliminary tests in the laboratory and an experiment where the main effects of factors have been studied, it appears that the binder contributes greatly in improving the thermal and mechanical properties of energy briquettes based on cocoa shells. Preliminary briquetting tests have shown that there is an optimal rate of incorporation of binder (9.4% -12.5%) making it possible to ensure good mechanical properties of the briquettes based on cocoa shells. The choice of binder was brought to the molasses and the cassava starch unlike the cassava skins which nevertheless presented good textural properties but a low impact resistance, which would limit their use because they will certainly not resist the various handling and transport conditions. It has also been observed that the incorporation of starch and sugar cane molasses as a binder improves the thermal properties of energy briquettes in that they greatly contribute to increasing the calorific value (19.80 ± 4, 69 KJ / kg). The combined effect of particle size and rate of incorporation by binding also influences the mechanical properties of the energy briquettes produced.

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Conflict of Interest

The authors declare no conflict of interest.

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