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Full Length Research Paper

Techniques for charring agricultural residues in a carbonizer "01 fût" for the production of biochar

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Abstract:
This paper deals with the possibilities of obtaining biomass coal carbonization method. Different agricultural residues (millet stalks, peanut shells, cashew shells, etc.) from the Casamance region have subjected to a heat treatment in a cylindrical metallic enclosure called carbonizer « 01 fût »). The carbonization yields of these three residues were evaluated and equal to 34.00 %, 34.07 % and 20.99 % respectively for peanut shells, millet stalks and cashew shells. Unburned fractions are respectively of the order of 0.5 %, 0.37 % and 8.95 %. Carbonization of cashew shell remains the slowest, the most difficult and was accompanied by release of the cashew nut shell liquid (CNSL).

Keyword: Agricultural residues; Biomass coal; Carbonization; Carbonization yields.

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1. Introduction

Providing a solution to deforestation is an environmental issue for the development of the developing countries, especially those in the south. Yet, a significant part of the forest has disappeared quite rapidly in recent years. Environment problems are compounded by health problems. According to 2012 WHO reports, 1.6 millions of women and children die each year from wood and charcoal smoke. So, we are all concerned because one of the most worrying threats at the moment is global warming due to greenhouse gas emissions. Open burning of agricultural residues and deforestation for the production of firewood and charcoal make the recycling and conversion of biomass waste a priority. Moreover, fuel briquettes produced from biomass residues have the potential to be a renewable energy source like so many other renewable energies (solar, wind turbines, thermal, hydraulic, etc.). In the majority of companies (BRADES, PRO-NATURA, GRET-ISET Rosso, BIOTERRE, etc.) producing fuel briquettes, the raw materials are first charred before being converted into biochar.

2. Literature Review

Carbonization of biomass is a slow combustion which takes place with a lack of air and a pressure greater than or equal to the atmospheric pressure (1013.25 hPa). Unlike rapid pyrolysis, this technique consists to produce the maximum of solid fraction at the expense of the liquid product. When the conditions for good carbonization are favorable, compared to the initial biomass, the coal has the advantage of containing twice as much energy per unit mass and being easy to pack in bags [1]. Depending on the performance of the processes, mass yields, depending on the biomass composition, reach an average of 30 % and the energy yields about 60 % [2, 3]. The objective of carbonization is to produce a solid fuel from the raw materials by optimizing the efficiency of the operation both quantitatively and qualitatively. This operation is conditioned by a number of factors (final and gradient temperatures, treatment time, moisture and raw materials composition, climatic conditions). The evaluation of the efficiency of the carbonization operation is conventionally carried out by determining the mass yield.

According to Schenkel et al. [4] the mass yield is calculated by the ratio of the mass of carbonized product to the mass of raw product initially introduced.

$$R_m = \left(\frac{M_C}{M_b} \right) \times 100 \quad \text{[Eq. 1]}$$

M_c : Mass of carbonized product (kg)
M_b : Mass of raw product (kg)
R_m : Mass yield (%)

According to the studies done by BIOTERRE Company [5], the carbonization yields of agricultural residues can reach 25 %.

3. Methodology

3.1. Raw materials

The experimental tests took place in a cylindrical metallic drum called carbonizer "01 fût" (**figure 1**). In the context of energetic conversion, biomasses that has a high calorific value and relatively low content of ash and moisture are more interest. Basing to the data of table 1, we made our first choice on certain agricultural residues (millet stalks, peanut shells, cashew shells and palm shells) coming from Casamance's region. The availability of these residues in Casamance area and their calorific value and their content of ash and humidity determine this choice.

Table 1: Summary of the proximate analysis and production estimation of biomass samples [6]

Wastes	FC (%)	VM (%)	Ash (%)	Humidity (%)	HHV (MJ/kg)	LHV (MJ/kg)	Amount (tons)
Peanut shell	19.60	65.40	9.30	5.70	19.57	18.48	391 570
Rice husk	18.50	57.40	15.70	7.30	15.72	14.89	142 100
Sorghum stalk	19.62	73.50	6.88	5.97	17.86	16.61	
Maize stalk	14.70	78.70	6.61	6.18	16.50	14.93	5 400 000
Millet stalk	18.70	78.30	5.3	6.10	19.41	18.12	
Sugar cane	31.00	65.00	3.60	9.40	18.90	17.60	11 000
Cotton stalk	15.12	75.77	2.70	6.41	18.10	16.74	81 530
Palm shell	14.48	77.96	7.56	6.20	22.99	21.45	97 600
Cashew shell	15.80	81.60	2.60	6.10	23.34	21.92	231 760

We remark, in table 1, that the agriculture residues have a high content of volatile matter. Thus, make carbonization of these residues contribute to increase the Fixed carbon and consequently the calorific value.

Fig.1: Picture of the carbonizer "01 fût"

3.2. Processes of carbonization

The carbonization is the most important step in the process of production of fuel briquettes. It consists to transform the biomass in a char. This char is obtained by carbonizing the dry biomass in controlled atmosphere (limited oxygen supply). In order to obtain good mass yield, the carbonizer is filled by the dry biomass. Concerning the millet stalks, they are, in first, cut to little pieces before being filled in the carbonizer. The carbonizer is then placed a few centimeters from the floor level. With a shovel, the space of entire periphery between the carbonizer and the floor level is covered with sand to make watertight. Before firing, four aeration holes are created at the base of the carbonizer. These holes must be diametrically opposite to facilitate a homogenous distribution of the heat. After igniting the carbonizer, some of the raw materials are burnt to provide the required heat for starting the carbonization. The carbonizer is lit from the top of the circular opening. The heat front moves from top to bottom. During the carbonization, the holes are often inspected. A hole is closed as soon as a fire has appeared. Also at the bottom of the carbonizer, another hole is opened to facilitate the movement of the fire inside the carbonizer. At the end of the carbonization, all the holes are clogged and the lid is closed by adding sand for sealing. The cooling process can take 3 to 5 hours.

4. Carbonization results

4.1. Char formation

The carbonization of the various residues leads in majority to the formation of solid products (Fig 2). When the carbonization is not well done, we obtain an unburned biomass.

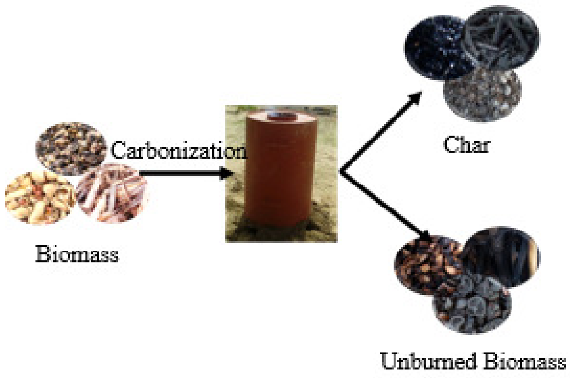

Fig. 2: Conversion of biomass into char

4.2 Carbonization mass yield

The data from the carbonization operation of peanut shells, cashew shells and millet stalks allow us to calculate the mass yields (**table 2**). Note that the carbonization of cashew shell remains the slowest, the most difficult and is accompanied by the release of the cashew nut shell liquid (CNSL). The cashew shells carbonization takes more time than those of peanut shells and millet stalks.

Table 2: Data of carbonization of the three residues

Wastes	Time of treatment (min)	Mass of biomass (kg)	Mass of char (kg)	Mass yield (%)
Peanut	86.00	27.00	9.20	34.07
Millet	42.00	20.00	6.80	34.00
Cashew	230.00	116.20	24.40	20.99

The mass yields of carbonization of peanut shells and millet stalks are around 30 %. Therefore, for large-scale production operations, a significant amount of biomass must be mobilized in order to obtain an important quantity of coal and avoid breaks during production. For the cashew shell, the mass yield is lower. This is certainly due to the release of the CNSL during the carbonization. It is therefore necessary to consider operating conditions in order to improve the mass yield.

As we have pointed out above, the carbonization of these residues does not totally give carbonized products. Unburned matter is also formed (see **table 3**).

Table 2: Mass distribution of the two products of carbonization

Wastes	Mass of biomass (kg)	Mass of char (kg)	Unburned biomass (kg)	Loss in other forms (kg)
Peanut	27.00	9.20	0.10	17.70
Millet	20.00	6.80	0.10	13.10
Cashew	116.20	24.40	10.40	81.40

The unburned matter during carbonization of cashew shells represents about 9 % by mass of the raw biomass. We remark that more than 60 % of the biomass is lost in other forms (ash, volatile matter, etc.).

4.3. Temperature variation inside the carbonizer

We have also tried to observe whether the barrel (carbonizer) temperature is homogeneous during carbonization. For this, an infrared thermometer (model KS Tools 150.3040, emissivity=0.95, distance spot ration=8:1) is used to measure, each five minutes, the temperature inside the carbonizer. **Fig. 3** shows the examples of temperature variation during carbonization of millet stalks, peanut shells, and cashew shells.

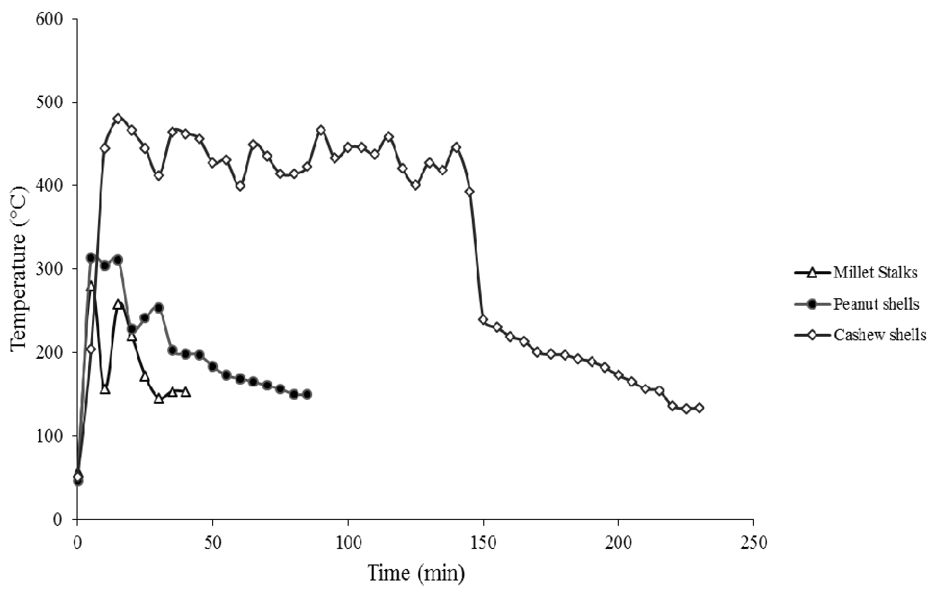

Fig.3: Variation of the temperature inside the carbonizer during carbonization of millet stalks, peanut shells and cashew shells

These graphs show that the temperature is not homogeneous inside the carbonizer during the process of carbonization. This temperature variability can influence the mass yield because the carbonization is accompanied by a partial combustion (that's why it is noted a loss of matter at the beginning of the carbonization of the charred matter.
We noted also the carbonization of cashew shells is done in a high temperature range (about 400 °C) during 145 minutes before falling to temperatures below 200 °C. These high temperatures are certainly the cause of the low mass yield when cashew shells were carbonized and this could be due to the presence of the liquid (CNLS), which acts as a fuel.
However, for cashew shells and millet stalks, almost all the carbonization takes place in a temperature range between 100 °C and 250 °C.

Conclusion

Carbonization is an important operation in the process of producing bio-charcoal. It must be controlled in order to guarantee high mass yields. In this study, mass yields have evaluated and are equal to 34.00 %, 34.07 % and 20.99 % respectively for peanut shells, millet stalks and cashew shells. Cashew shells, which has a low mass yield, is difficult to carbonize because of the liberation of cashew nut shell liquid (CNSL).

We intend to find some techniques to improve its mass yield and, if possible, recover the CNSL.

Note that this study consists of preparatory work to study the effects of charcoal briquettes characteristics in the composition of emissions during burning the residues in domestic cooker used in Senegal.

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