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RESEARCH ARTICLE

A MODEL OF ECOLOGICAL CHARCOAL PRODUCTION THROUGH HERBACEAOUS PLANTS IN THE URBAN COMMUNE OF N'ZEREKORE, REPUBLIC OF GUINEA

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Abstract

The world is confronted to various environmental problems caused by anthropogenic activities, mainly deforestation. This is why promoting the use of herbaceous plants in charcoal production will contribute to the fight against deforestation. In this paper we propose a simple model for producing ecological charcoal using herbaceous plants. The choice of the herbaceous species, the collection, weighing, drying, carbonization, crushing, sieving, kneading, compacting and drying of the briquettes are the different process which allowed us to produce this ecological charcoal based on herbaceous plants. 180kg of soaked weight of herbaceous gave us 90kg of dry weight, carbonized and crushed we obtained 8kg of powder and 1 kg of residue. These 8 kg of herbaceous powder allowed us to produce 156 briquettes of charcoal. A comparison of the physicochemical parameters of our ecological charcoal was made with the charcoal consumed in the urban commune of N'zérékoré (wood charcoal). The Results showed that our produced charcoal model releases heat more slowly than wood charcoal, heats up more slowly than wood charcoal and its maximum temperature and heat quantity are higher than that of wood charcoal. The maximum temperature (98.9°C) is reached at 20 minutes for ecological charcoal (charcoal from herbaceous plants) and 97.9°C at 10 minutes for wood charcoal.

Introduction:-

Energy is a crucial factor for the functioning of a country's economy and the improvement of people's living conditions. No development is possible without it. In non- developing countries, one of the main uses of energy is cooking, often provided by the direct combustion of wood and its derivatives. Each year, 47 million tonnes of charcoal are produced globally, with 50% of harvested wood used for cooking, with 17% transformed directly into charcoal [1]. Deforestation, exacerbated by human activities such as agriculture and charcoal production, is a major concern for environmental protection. Every year, around 13 million hectares of forests disappear, endangering biodiversity and worsening environmental and health problems [2]. In Africa it is more than 3.4 million hectares of forest destroyed every year [3]

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In Africa, wood energy (firewood, charcoal, sawdust, chips) constitutes more than 80% of the energy supply [4]. In West Africa, nearly 90% of the population uses wood energy for cooking and heating [5].Firewood and charcoal represent 90% removal from African forests and a third of global wood energy production [6]. In Cameroon, biomass represents 74.22% of total energy consumption, followed by oil (18.48%) and electricity (7.30%) [7].

In Guinea Republic, the increasing management of wood energy is leading to a reduction in forests and degradation of wooded areas. Peri-urban forests are disappearing, replaced by anarchic crops and construction. Charcoal consumption is increasing in rural areas, with inefficient carbonization techniques. The informal artisanal sector consumes 971,226 tonnes of wood and 49,212 tonnes of charcoal annually [8]. The high consumption of wood energy, particularly for fish smoking and salt extraction, accentuates this pressure.

In the urban commune of N'Zérékoré, a large part of the population depend heavily on wood charcoal for cooking and heating. This practice, although traditional and deeply rooted in local culture, causes serious environmental and health problems. Massive deforestation and the forest ecosystems degradation are the direct consequences of this dependence, leading to a loss of biodiversity and an increase in greenhouse gas emissions. Therefore, it is crucial to explore and promote new sustainable energy sources, such as green charcoal produced from herbaceous plants. [9] Indicates Green charcoal can be used as a substitute for wood charcoal, firewood for domestic cooking or even heat production in industries.

Faced with these challenges, the energy recovery of herbaceous plants presents economic, energy and environmental advantages. Herbaceous plants, available in abundance, can be converted into eco-friendly charcoal, providing a renewable substitute for wood charcoal. This process involves several steps, from collection to drying, carbonization and compaction.

The calorific value of produced green charcoal ranges between 16.98 and 32.16 MJ/kg, the humudity content is less than 8% and the fixed carbon content is between 15.15 and 19.49%. According to the analysis of the green charcoal production system, this process is shown to be green in terms of energy, with primary energy consumption varying from 0.09 to 0.56 kWh for each kilowatt hour of energy produced [10].

Promoting the manufacturing of ecological charcoal in the urban commune of N'Zérékoré represents an opportunity to respond to the region's energy, environmental and economic challenges. It is to make a contribution to this problem that this research was carried out for the valorization of herbaceous plants in the production of charcoal in the urban commune of N'zérékoré.

Green charcoal production is currently a current research topic addressed by several researchers. Ecological charcoal production from agricultural waste is addressed [11]. Production and characterization of environmentally friendly charcoal briquettes obtained from agriculture waste: case of cameroon is adressed in [12].

Materials:-

Study Area

This study was carried out at the Nzérékoré University, Republic of Guinea. The University of N'Nzérékoré is located in the Nakoyakpala district. This district is located to the west of the urban commune of N'Zérékoré on the N'Zérékoré-Yomou national road. It is limited to the east by the Gbangana district, to the west by the locality of Kéréma, to the north by the Mohomou district and to the south by the village of Theyegno. Figure 1 represents the map of the University of Nzérékoré.

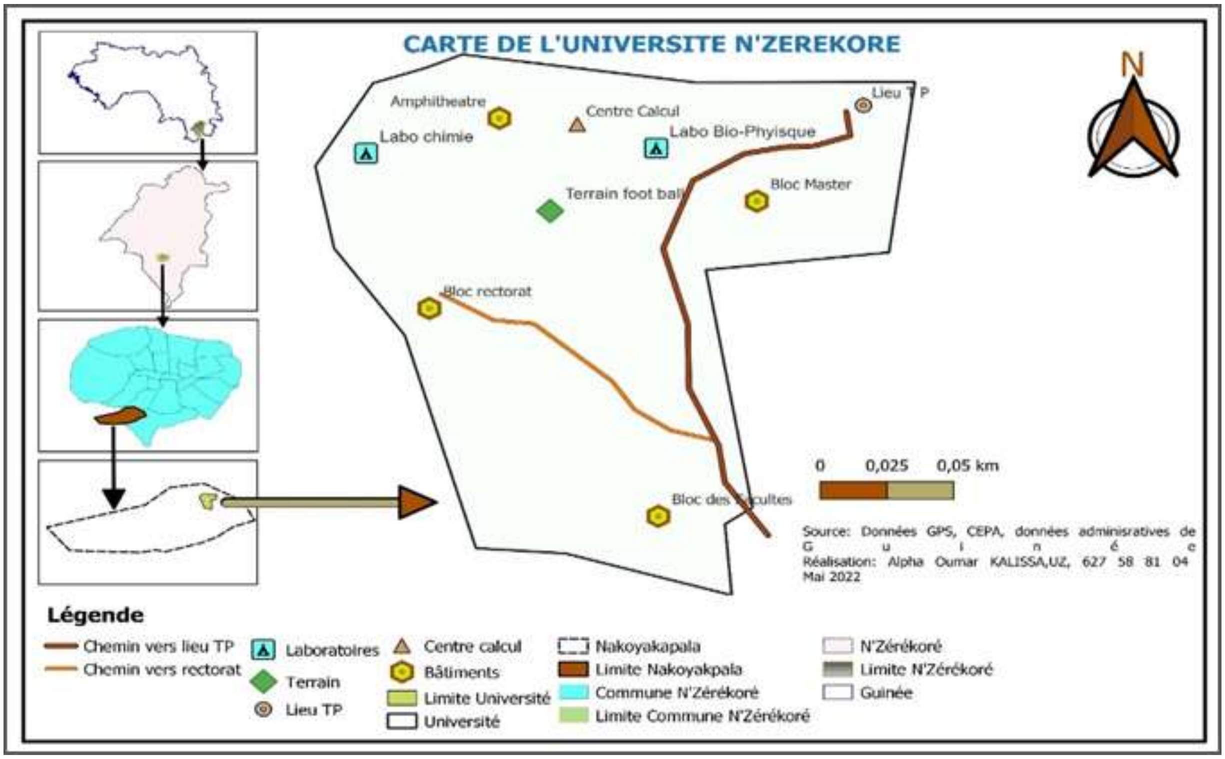


Figure 1:- Map of the University of Nzérékoré.

Raw materials

Choice of herbaceous species

The choice of species for the production of ecological charcoal from herbaceous biomass is a crucial element to guarantee the sustainability and efficiency of the process. Here are some criteria to take into account when selecting for the production of ecological herbaceous charcoal.

Biomass yield: it is important to choose herbaceous species with high biomass yield to maximize charcoal production. Species like Miscanthus, bamboo and some varieties of Andropogongayanus are very rich in biomass.

Lignocellulose content: Species rich in lignocellulose can be good candidates for charcoal production, as they contain a significant amount of carbon necessary for the production of charcoal of good quality. Herbs such as Miscanthus and Andropogongayanus are rich in lignocellulose and can be good choices for the production of ecological charcoal.

Rapid growth potential: Choosing fast-growing species can be beneficial in ensuring a regular supply of biomass for charcoal production. Some herbaceous species such as bamboo, miscanthus and Andropogongayanus have rapid growth potential which makes them attractive for charcoal production.

Adaptability to local conditions: it is important to choose herbaceous species that are adapted to local climatic and environmental conditions [13], [14]. This will minimize input requirements and promote more sustainable production.

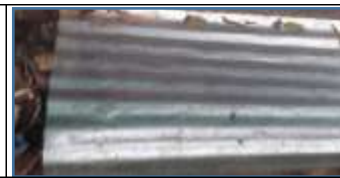
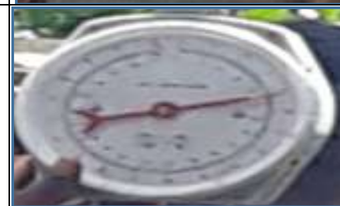
Taking these criteria into account, it is possible to select the best herbaceous species for the production of ecological charcoal, ensuring efficient, sustainable and environmentally friendly production. Figure 2 gives the collect and transportation of herbaceous (Andropogongayanus) used in this study.

Figure 2;-Herbaceous collect and transportation.

To carry out this research, we used certain materials and equipments essential for the ecological charcoal production process.

Table 1:- Materials used in production process.

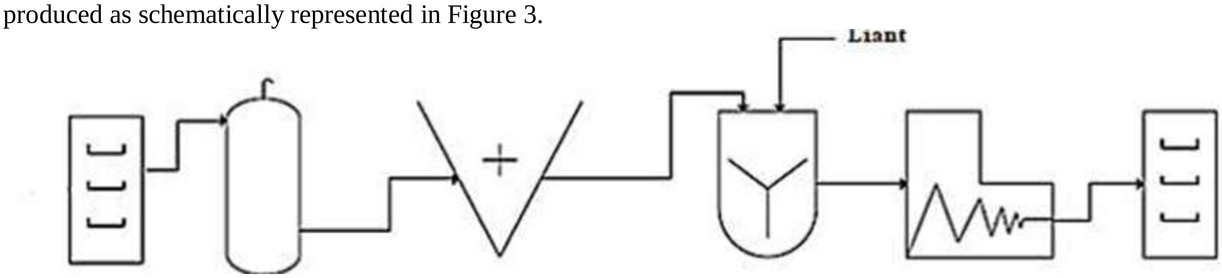
Materials	Function	**Images**
The oven or barbecue	Allows thermal decomposition of organic matter in the absence of oxygen.	
The sieve	Allows separation of large particles from fine particles after crushing	
The crusher	Allows you to crush carbonized material	
Compactor (mold)	Facilitates the compaction of the mixture to obtain green charcoal briquettes.	
Bouillard (saucepan)	Allows to heat the water used for preparing starch	

Sheet metal	Used for sorting carbonized material and drying the briquettes produced.	
Toggle or measuring device	Tool used for weighing matters.	
Sacs Bags	Tool used for weighing cut matters	
Machetes	Used for cutting and cut out herbaceous plants	
Thermo flash	Use to measure the temperature.	

Methods:-

Ecological charcoal production process

In this study, the ecological charcoal production process follows the following steps. Herbaceous collection, herbaceous drying, carbonization, crushing, mixing with addition of binder, compaction and drying of the briquettes produced as schematically represented in Figure 3.



Drying Carbonization CrushingMixing Compacting Briquettes drying

Figure 3:- Schematically representation of ecological charcoal production process.

Drying

The step following the collect is that of drying operation. Drying is an important phase of production because if all herbaceous plants can produce briquettes, only dense and dry herbaceous plants will make it possible to obtain good quality of charcoal powder. It lasted for 5 days. We put the herbaceous plants (Andropogongayanus) under the sun at room temperature.After drying operation (Figure 4) we obtained a quantity of 90 kg of dry matter from 180kg of humudAndropogongayanus.Humidity is now computed by thefollowing relation:

Humidity (%)= $\frac{soakedweight-dryweight}{soakedweight} \times \mathbf{100}\%$ (1)

a) b)

Figure 4:- Herbaceous (Andropogongayanus) state: a) humid, b) dry.

Carbonisation

This is a very important step in the green charcoal production process which consists of causing the chemical decomposition of the raw material through the action of heat in order to obtain a product composed mainly of carbon. The dry residues are placed in oven barrels topped with chimneys as shown in the Figure 5 and burned until transformed into completely black solids [15]. This operation can last 35 minutes for very dry Andropogongayanus and approximately one hour and thirty minutes for less dry ones.

Figure 5:- Carbonization of the herbaceous in the oven.

Crushing

The aim of this step is to reduce the carbonized product to powder; It is recommended to crush the carbonized biomass to a particle size less than 5 micrometer [16]. This step must be well articulated to facilitate the mixing of the black powder obtained. Figure 6 shows the crushing operation used in this study

Figure 6:- Crushing process of herbaceous.

Sieving

The sieving was carried out with a sieve made from metal mesh. After sieving operation we obtained a quantity of carbonized powder of 8 kg in total (Figure 7).

Figure 7:- Sieving the powder of the herbaceous charcoal obtained.

Mixing with added binder

Mixing consists of binding the particles of the powder obtained after crushing. This operation is done using a binder and a mixer, and ensure adhesion between powder particles and the strength of the briquettes. The Figure 8 below shows a mixer operating with hands used in this study.

Figure 8:- Sieving the powder of the herbaceous obtained.

A binder is a non-brittle, flexible, elastic element suitable for binding. It allows to ensure cohesion between two products difficult to mix. The binders most used in the production of ecological coal are: starch and clay. In this study we use starch as binder. Starch is extracted from potatoes, barley, wheat, or cassava. In this case of ecological charcoal production starch is extracted from cassava tubers which is the most used because of its easily accessibility

Binder preparation

To prepare the binder with the starch, we boiled the water, poured cassava flour into a small quantity of cold water then kneaded, then poured the mixture into the boiling water and stirred until a change texture intervenes. For the preparation, we used 1.33 liters of boiling water for 0.13 kg of cassava flour. This dose was used to mix with 2 kg of carbonized Andropogongayanus powder.

Compacting

Compaction gives the final shape to the green charcoal. We generally distinguish the parallelepiped, cylindrical or spherical (ball) shape. For this we can use a compactor like the one shown in the Figure 9. The compaction is realize as following:

- ✓ Introduce the dough produced by mixing into the compactor mold;
- ✓ Depending on the operation of the compactor used, subject the charcoal to strong pressure until it is well compressed;
- ✓ Remove the resulting briquettes from the mold and prepare them for drying.

It is important to mention that when the charcoal produced don’t have high density because it is not very compressed, it burns at a high speed and therefore consumes very rapidly. The compaction force has an impact on the combustion rate because it will be less homogeneous in the case of manual compaction than of mechanical compaction. Figure 9 illustrates the compacting process.

Figure 9:- Sieving the powder of the herbaceous obtained.

Results and Discussion:-

Briquettes final drying

The final step of ecological charcoal production process consists of drying the final product (briquettes) in the sun or using a dryer, in order to facilitate its combustion. In fact, it is the water introduced at the alloying stage that we want to eliminate[17], [18]. To release a good amount of energy during combustion, green charcoal should have a humidity level less than 10%. The Figure 10 illustrates final drying of green charcoal briquettes.

Figure 10:- Briquettes final drying.

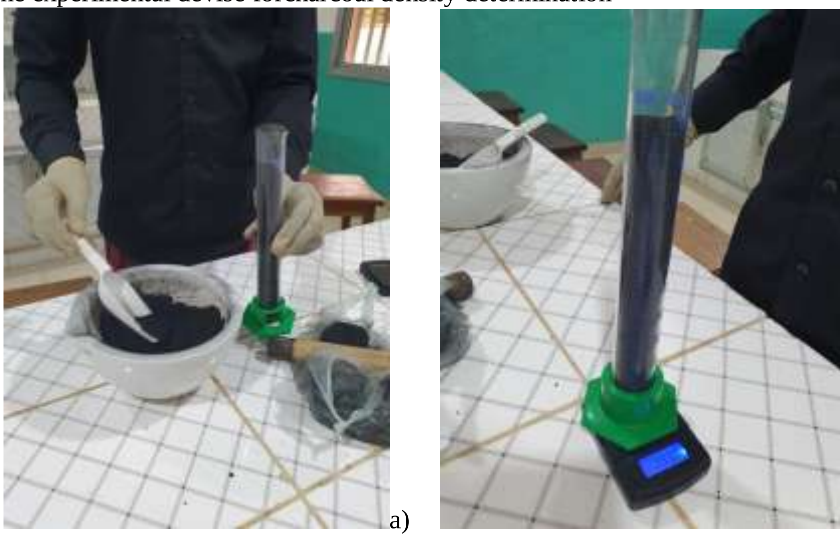
Physicochemical characterization of briquettes
After briquettes production, we proceed to their physicochemical characterization. This experimental part was performed at chemical laboratory of Nzérékoré University.

Density
To determine the density of the ecological charcoal, we used a graduated cylinder (100ml) which we inserted into the green plastic foot and weighed it on a balance. Then the graduated test tube is filled with sifted ecological charcoal powder using a plastic shovel, then compacted by gently tapping the test tube on a closed surface until it reaches 100ml, it is then placed on the balance and its weight is raised. The difference of the two weights makes allows to obtain the mass of the ecological charcoal powder on a volume of 100ml. The density is then computed as following

Density=$\frac{\boldsymbol{m}\,(\boldsymbol{g})}{\boldsymbol{V}(\boldsymbol{mL})}$(2)

Where **m** is ecological charcoal mass, **V** is the volume (100ml).

Figure 11 shows the experimental devise forcharcoal density determination



a) b)

Figure 11;-Charcoal density determination a) filling the graduated cylinder, b)weighing graduated cylinder filled with ecological charcoal powder.

Humidity
To determine the humidity, we weighed 100g of the soaked charcoal powder sample, then we inserted it into the oven at 105°C for 1 hour. After drying, we put the sample back in the beaker then used the balance to zero. The following formula was used to calculate humidity.

Humidity (%) $=\frac{\boldsymbol{soakedweight}-\boldsymbol{dryweight}}{\boldsymbol{soakedweight}}\times\mathbf{100}\%$(3)

After drying and determining thephysico-chemical parameters, below the list of the main results obtained. We used 180 kg as the soaked weight of herbaceous (Andropogongayanus). After drying we obtained a dry weight of 90 kg. From this 90 kg of dry herbaceous, we obtained 8kg of calcined powder after carbonization which allowed us to produce 156 briquettes as a finished product and 1kg as residue. The unit weight of briquette is 120 g including 18720 g in total for all briquettes, the volume of one briquette is 62.8 cm^3 and of 9796.8 cm^3 for all briquettes. The unit density of briquettes is equal to 1.91 g/cm^3 and a total of 297.96 g/cm^3 for all briquettes. These results are summarized in the table below.

Table 2:- Physicochemical parameters of briquettes.

Briquettes parameters	Unit value	Number of Briquettes	Total value
Weight	120g		18720g

Voulume	62.8cm^3	156	9796.8cm^3
Density	1.91g/cm^3		297.96g/cm^3
Humidity	37,90%		

Combustibility tests of produced briquettes

To test the combustibility of our ecological charcoals produced (charcoal from herbaceous plants), we first compare their physicochemical properties to those of charcoal consumed in Nzérékoré city (Figure 12 a-b). This charcoal is from wood

a) b)

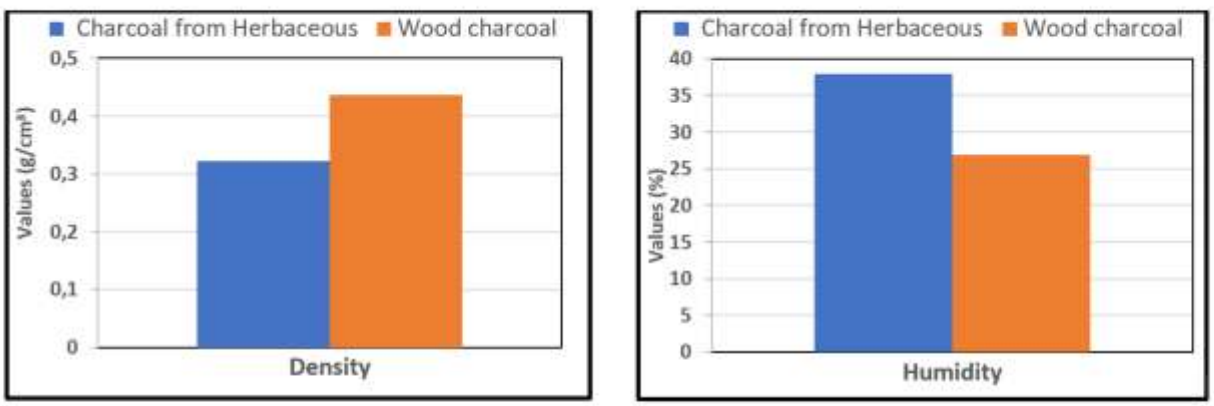


Figure 12;-Comparison of charcoal physico-chemical parameters, a) density, b) humidity

For the second comparison phase, we used two furnaces filled with 300 g of charcoal each. The first filled with ecological charcoal and the other with classical charcoal. Then two pots of the same type, each containing ½ liter of water, were each placed on a furnace and both putted on the fire at the same time with the same initial temperature (Figure 13). Then we started a timer to determine the boiling time, the evolution of the water temperature in each pot and subsequently determined the quantities of heat released by the waters though the combustion of each of the two charcoals. The total consumption time of the two charcoals was also determined.

a) b)

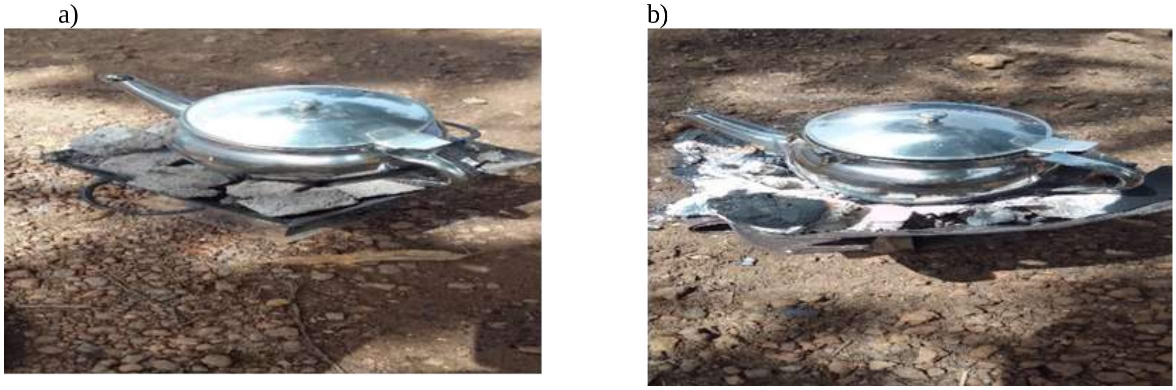


Figure 13:-Combustion process of the twos charcoal types. a) charcoal from herbaceous, b) wood charcoal

Figure 14 shows the temperature evolution of water with time for the two pots each heated by a type of charcoal.

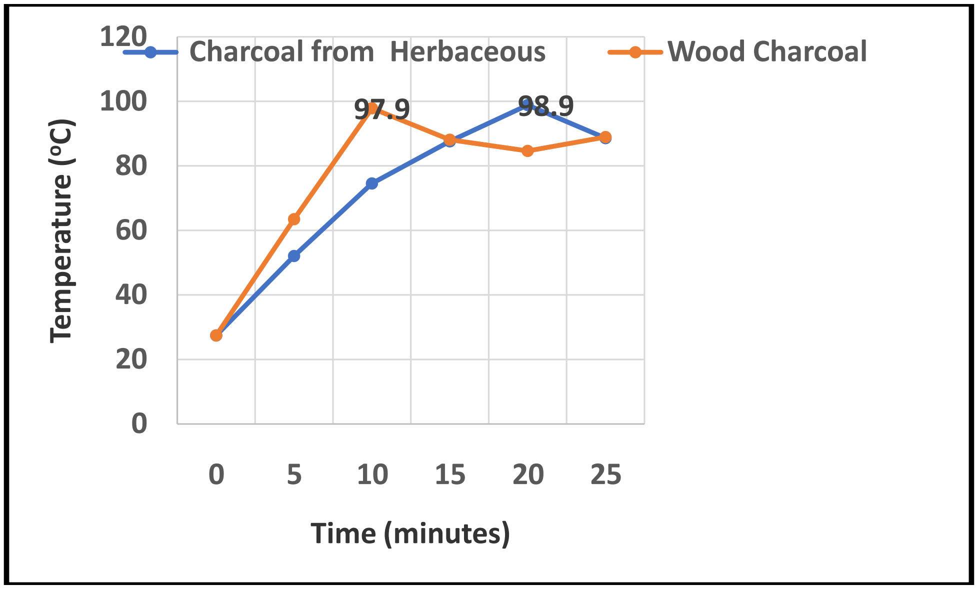


Figure 14;- Temperature evolution with time for the spots heated respectively by herbaceous charcoal and wood charcoal.

Figure 14 shows that the water heated by herbaceous charcoal reaches its maximum temperature later than that heated by charcoal. The maximum temperature is reached at 20 minutes for ecological charcoal (charcoal from herbaceous plants) and 10 minutes for wood charcoal. Figure 15 gives the comparison of temperatures at every five minutes between the two spots (the two charcoal type).

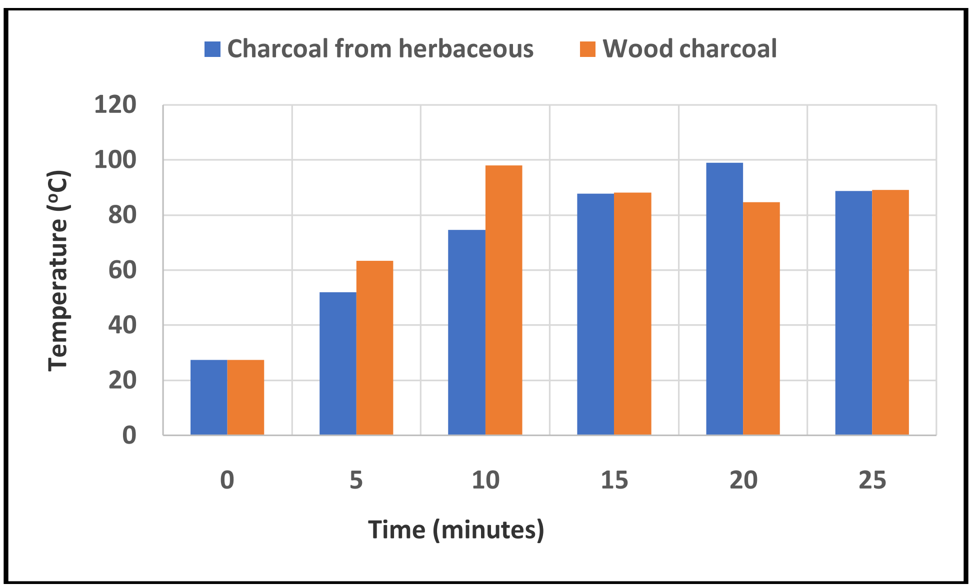


Figure 15:- Comparison of temperatures at every five minutes between the two spots (the two charcoal type.

From Figure 15 we can see from 5 to 10 minutes wood charcoal heats up faster than ecological charcoal, around 15 minutes the two charcoal types reaches the same temperature and from 15 to 20 minutes ecological charcoal temperature is higher than wood charcoal. The temperature of ecological charcoal increases gradually from 27.4°C to 98.9°C at 20 minutes before dropping back to 88.7°C at 25 minutes . For wood charcoal the temperature increases gradually from 27.4°C to 97.9°C at 15 minutes before decreasing to 89°C at 25 minute.

From the Figure 14 we calculated the heat quantity release by the waters of the twos spots heated by the two charcoal types. The result is represented in Figure 16. As it can be remarked the heat quantity curve have the same trends as the temperature curves. The water heatby the ecological charcoal (charcoal from herbaceous) release this maximum quantity of heat later (20 minutes) than wood charcoal (10 minutes).

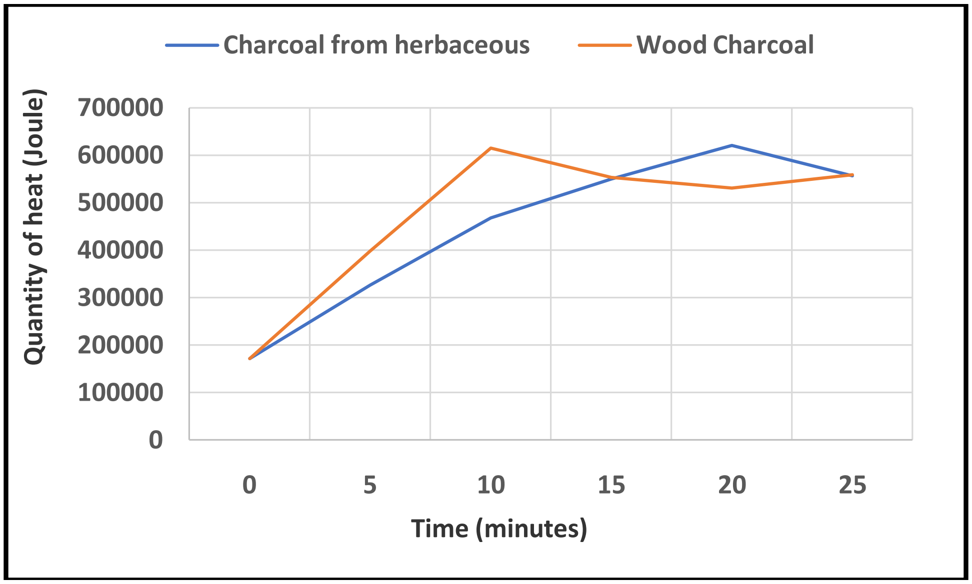


Figure 16:-Heat quantity release by the waters of the twos spots heated by the two charcoal types.

Figure 17 illustrates the comparison between the two charcoal types in terms of combustion time. It can be seen that the total combustion time of ecological charcoal (charcoal from berbaceous) is longer than that of wood charcoal. This constitutes an advantage of the ecological charcoal produced

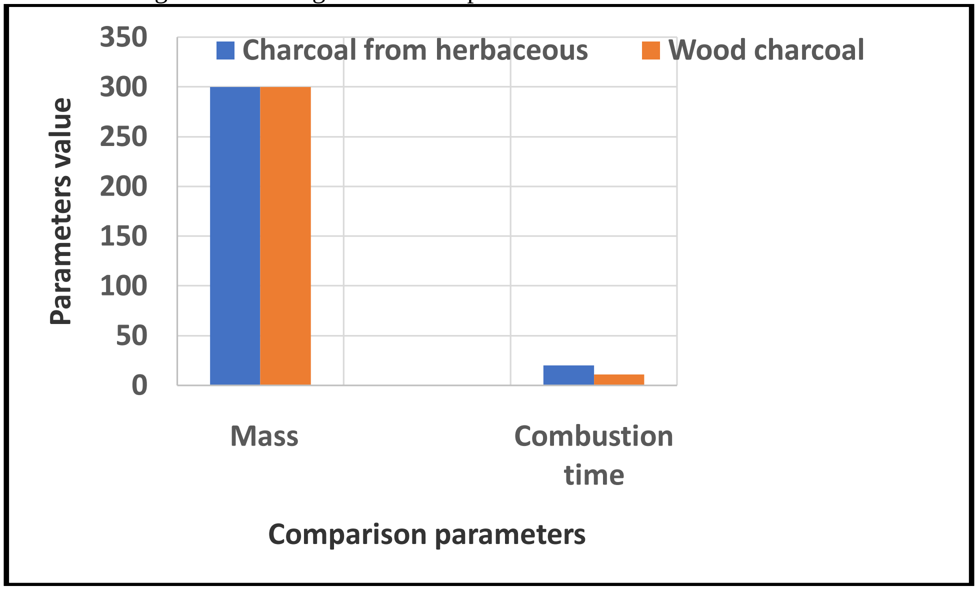


Figure 17:-Comparison of combustion time between the two charcoal.

Figure 18gives the comparison ofthe two charcoal state during and the end of combustion

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During combustion WC | End of combustion WC | During combustion CFH | End combustion CFH

Figure 18;- Comparison of the two charcoal state during and the end of combustion

Legend. WC: Wood charcoal
CFH: Charcoal from herbaceousC

Conclusions:-

This work contributed to the promotion of the green economy in the urban commune of N'zérékoré through the production of ecological charcoal.

Based on scientific studies, the biomass to be valorized (Andropogon gayanus) have been identified and characterized. Then a technique for producing green charcoal based on these herbaceous plants was proposed. The production process is composed of seven steps: choice of herbaceous species, collection, weighing, drying, carbonization, crushing, sieving, kneading, compacting and drying of the briquettes obtained.

180kg of soaked weight of herbaceous gave us 90kg of dry weight, carbonized and crushed we obtained 8 kg of powder and 1 kg of residue. These 8 kg of herbaceous powder allowed us to produce the 156 briquettes. A comparison of the physicochemical parameters of our ecological charcoal was made with the charcoal consumed in the urban commune of N'zérékoré. The Results showed the produced charcoal model releases heat more slowly than wood charcoal, heats up more slowly than wood charcoal and its maximum temperature and heat quantity are higher than wood charcoal. The maximum temperature (98.9°C) is reached at 20 minutes for ecological charcoal (charcoal from herbaceous plants) and 97.9°C at 10 minutes for wood

Regarding a qualitative study of the ecological charcoal obtained, it was possible to demonstrate the herbaceous species used in this study (Andropogon gayanus) presents better energy efficiency than wood charcoal. This study could open the door to the use of other forms of herbaceous plants for the production of green charcoal such as (mint, basil, rosemary etc...).

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