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Research Article

A New Model of Ecological Charcoal Production by Pig Manure in the Urban Commune of Nzérékoré, Rupblic of Guinea

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Abstract

In Guinea, several communities lack energy supply for daily household needs, including cooking. People often resort to burning wood to fill these energy gaps. The deforestation generated is becoming increasingly worrisome, with multiple environmental consequences. In this context, an alternative to abusive wood cutting must be found in order to contribute to the fight against deforestation. This paper proposes a new model for ecological charcoal production using pig manure. The pig manure collection, weighing, drying, carbonization, crushing, sieving, kneading, mixing with the addition of binder, compacting and drying of the briquettes are the different process which allowed us to produce this ecological charcoal trough pig manure. With 9kg of carbonized powder, we obtained 120 briquettes of pig manure charcoal. Then a physicochemical characterization of the ecological charcoal briquettes produced from pig manure was made, the density and humidity rate determined are respectively 0.88g/cm^3 and 54.84%. Finally, we carried out a combustibility test of the ecological charcoal produced. To do this, a comparison of the physicochemical properties between our ecological charcoal produced and the wood charcoal consumed in the city of Nérékoré. The results showed that the manufactured ecological charcoal (charcoal from pig manure) is denser and more humid than wood charcoal. In terms of boiling temperature, pig manure charcoal reaches its maximum temperature later than wood charcoal. The maximum temperature (80.6 °C) is reached in 30 minutes for ecological charcoal (pig manure charcoal) and (92 °C) in 15 minutes for wood charcoal.

Keywords

A New Model, Valorization, Carbonization, Charcoal, Ecological, Pig Manure, Production

1. Introduction

Cooking is one of the most important activities of daily household needs in non-developing countries. The energy required is mainly provided by the direct combustion of wood and its derivatives. In [1] it is indicated that year, 47 million tonnes of charcoal are produced globally, with 50% of harvested wood used for cooking, with 17% transformed directly into charcoal. In Africa, wood energy (firewood, charcoal, sawdust, chips) constitutes more than 80% of the energy supply [2].

In West Africa, almost 90% of the population uses wood

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energy for cooking activities and heating [3]. Firewood and charcoal represent 90% removal from African forests and a third of global wood energy production [4].

In Guinea Republic 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 [5].

In the urban commune of N'Zérékoré most of the population depend strongly on wood charcoal for cooking and heating causing 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 ecological charcoal production.

Several researches have been carried out on ecological charcoal production technique. [6] indicates Green charcoal can be used as a substitute for wood charcoal, firewood for domestic cooking or even heat production in industries. Studies of ecological charcoal production from agricultural waste are performed in [7-9]. Ecological charcoal from herbaceous plants was recently produced in [10]. Sustainable charcoal production from biomass was investigated in [11]. An Analysis of charcoal production with recent developments in Sub-Sahara Africa is carried out in [12]. Study of effects of operating variables on durability of fuel briquettes from rice husks and corn cobs is illustrated in [13]. Another research work on charcoal production by agriculture waste is presented in [14]. Charcoal briquettes production from agro-industrial waste with cassava industrial binders is in [15]. [16] indicates in Africa, Asia, and Latin America charcoal from carbonization is used by almost 89%, 77%, and 35% of households respectively.

Despite this extensive research on ecological charcoal production, there is almost no research on ecological charcoal production from animal waste. In this paper we propose a new model of ecological charcoal production by pig manure in the urban commune of Nzérékoré, Rupblic of Guinea. This paper has the following structure. After the introduction section section above, the Materials and Methods section is presented in which the study area is described first followed by the ecological charcoal production method using pig manure. At the end the Results and Discussion Section is presented.

2. Materials and Methods

2.1. Study Area

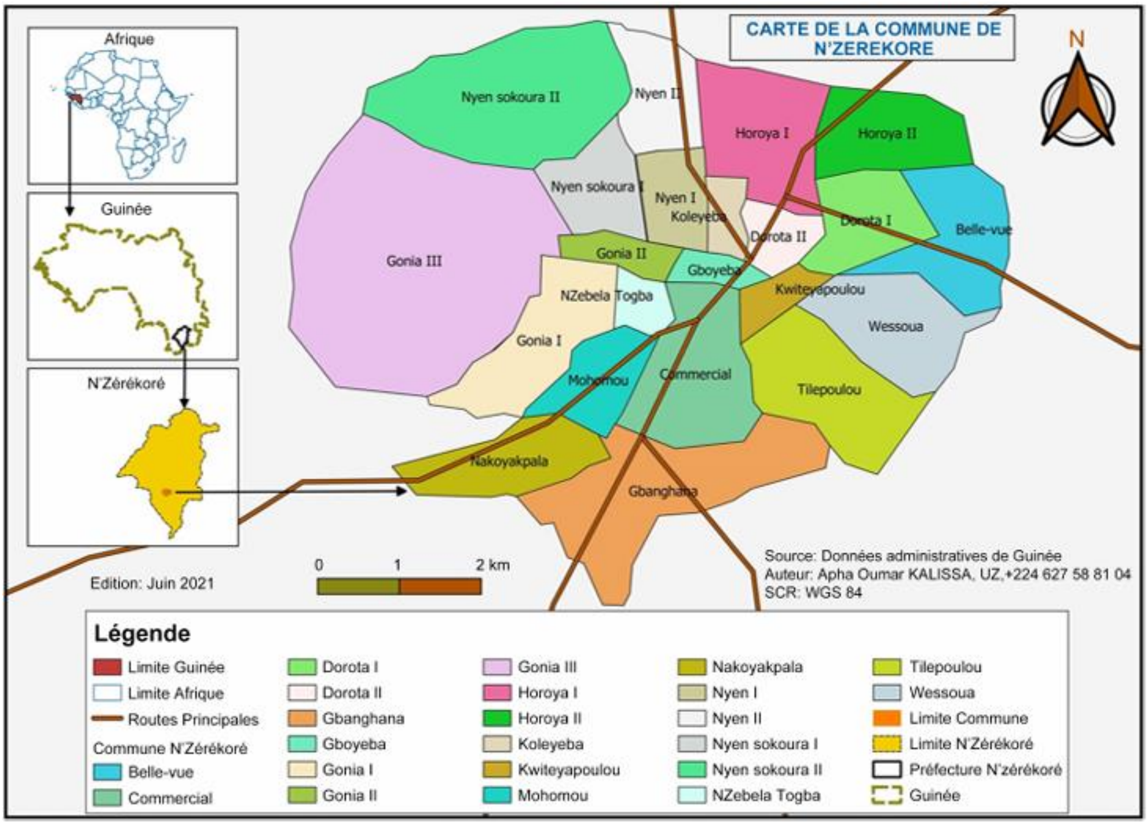

Figure 1. *Map of the city of N'Zerekore.*

This study was carried out in Nzérékoré city. It is one of the 33 cities of Guinea and the largest city in Forested Guinea, a region in the southeast of the Republic of Guinea. The city is also the capital of the Forest region located between 7°32 and 8°22 north latitude and 9°04 west longitude, extending over 47.3 km². The distances to neighboring cities are 39 km from N'zérékoré to Lola, 62 km from N'zérékoré to Yomou, 125 km from N'zérékoré to Beyla, and 135 km from N'zérékoré to Macenta. N'zérékoré is situated at an elevation of 480 meters, and its terrain is rugged. The plateau is domi nated by hills, which are sometimes gneissic (Gonia) and sometimes quartzitic (Gboyéba). The city features three significant mountains: Götö (450 m), Hononye, and Kwéléyé (350 m). Nakoyakpala is one of the 22 neighborhoods of the urban commune of N'zérékoré, bordered to the east by the rural commune of Bounouma, to the west by the Tilé River and the Mohomou district, to the south by the Kérémé district, and to the north by the Gbangana district and the Tilé River. Figure 1 represents the map of the city of N'Zerekore.

2.2. Raw Materials

The raw materials in this study are pig manure from modern pig breeding.

2.3. Process of Ecological Charcoal Production from Pig Manure

The ecological charcoal production process in this study follows the next steps: pig manure collection, drying, carbonization, crushing, mixing with addition of binder, compaction and drying of the briquettes produced. The well-known scheme illustrating these steps is shown in Figure 2.

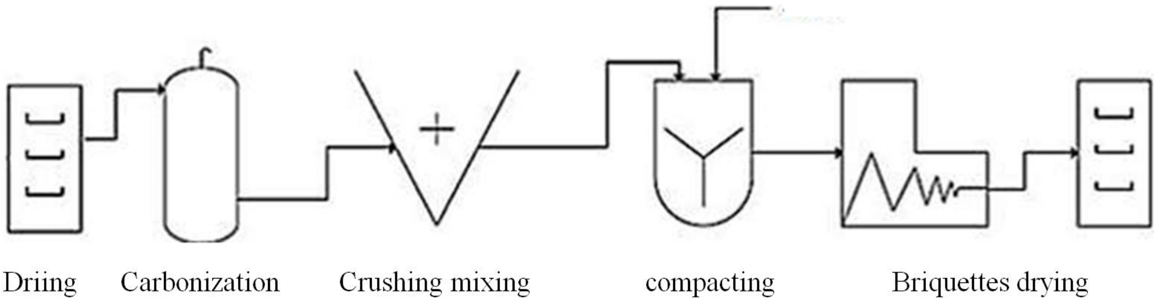

Figure 2. *Ecological charcoal production process scheme [10].*

2.3.1. Pig manure Collection

This step involves the pig manure collection that constitute the raw material for the production of briquettes (as illustrated in Figure 3).

Figure 3. *Pig manure collection.*

2.3.2. Weighing and Drying

After collection operation pig manure were weighed, dried and weighed again. For this, we used a scale which allowed us to obtain 62kg as wet weight and 28kg as dry weight after drying. This is an important phase of production because it allows to obtain good quality of charcoal powder during the next step which carbonization process. Figure 4 illustrates weighing and drying phases.

Figure 4. *Weighing and drying operation.*

This above weighing and drying operation allowed us to calculate the humidity level of pig manure as follows:

$$Humidity\ (\%) = \frac{wetweight - dryweight}{wetweight} x100$$

2.3.3. Carbonization

Carbonization is the most important step in ecological charcoal production process, it allows to decompose chemically the raw material by the action of heat to obtain a product composed largely of carbon. Using the carbonizer, the dry pig manure are burned until they turn into completely black solids. In our case, 128 kg of dry pig manure substrates were carbonized for approximately 4 hours and 30 minutes to obtain 9kg of carbonized black powder. Figure 5 illustrates the carbonization operation and the state of pig manure after carbonization.

Figure 5. *Carbonization operation.*

2.3.4. Crushing

The aim of this operation is to reduce the carbonized product to black powder. It is needed to crush the carbonized biomass to a particle size less than 5 micrometer [17, 18]. This step constitutes an essential step for the success of the mixing operation of the black powder obtained and it is presented in Figure 6.

Figure 6. *Crushing operation.*

2.3.5. Sieving

The sieving operation was performed thank a metal mesh sieve. The quantity of carbonized black powder obtained after sieving operation is 9 kg. The sieving operation is represented in Figure 7.

Figure 7. *Sieving operation.*

2.3.6. Binder and Mixing Operation

Mixing operation allows binding the particles of the black powder obtained after crushing and sieving. It is done by using a binder and a mixer. This operation ensure adhesion between powder particles and the strength of the ecological charcoal briquettes. A binder is a non-brittle, flexible, elastic element suitable for binding [10]. It allows to establish cohesion between two products difficult to mix. The binders often used in ecological charcoal production are: starch and clay. In this work have used starch as binder. Starch is extracted from potatoes, barley, wheat, or cassava. In our case, starch is extracted from cassava tubers which is the most practiced for reason of its easily availability. The Figure 8 shows a hand used mixing operation in this work. Binder preparation was made as in [10].

Figure 8. *Binder and mixing operation.*

2.3.7. Compaction Operation

Compaction is an important step in the production of ecological charcoal. It allows giving the final shape to the ecological charcoal in the form of briquettes. In most of the cases the briquettes have. parallelepiped, cylindrical or spherical (ball) shape. In this study a compactor like the one shown in the Figure 9 were used. The compaction is realized as following: 1- introduce the dough produced by mixing into the compactor mold, 2- depending on the operation of the compactor used, subject the charcoal to strong pressure until it is well compressed, 3- 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 [10]. Figure 9 illustrates the compacting process and the briquettes produced.

Figure 9. *Compaction operation ecological charcoal briquettes obtaining.*

2.3.8. 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 obtain good quality of combustibility. The Figure 10 illustrates final drying of our ecological charcoal briquettes produced using pig manure. In our case, 120 briquettes of pig manure charcoal were obtained with the 9kg of carbonized powders.

Figure 10. *Briquettes final drying.*

2.3.9. Charcoal Briquettes Physicochemical Characterization

Density

The produced briquettes density was determined as following:

$$density = \frac{m(g)}{V(m^3)} \quad (1)$$

Where m represents the briquette mass, V its volume.

As the briquette has cylindrical shape (see Figure 10), its volume is calculated using the relationship below

$$V = \pi \times R^2 \times H \quad (2)$$

With R, the radius of the briquette (R =2.75) cm and H its height (H =3 cm). After weighing, the mass of a briquette is 62.5 g. The calculated volume of a briquette is therefore V =71.24 cm^3. From equation 3, the briquette density computed is 0,88g/cm^3.

Humidity

To determine the humidity, we weighed 100g of the soaked briquettes powder sample, then we inserted it into the oven at 105 ℃ for 1 hour. After drying, we put the sample back in the beaker then used the balance to zero (see [10]). The following formula was used to calculate humidity

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

3. Results and Discussion

Table 1. *Physicochemical parameters of briquettes.*

Briquettes parameters	value
Mass (g)	62.5
Volume (cm^3)	71.24
Density (g/cm^3)	0,88g
Humidity (%)	

After drying briquettes and determining the physicochemical parameters, the following results are obtained. 128 kg of dry pig manure substrates were carbonized for approximately 4 hours and 30 minutes to obtain 9kg which allowed to obtain 120 briquettes. Table 1 summarizes the produced briquettes physicochemical parameters.

Briquettes Energy Efficiency Test

For the combustibility test, we conducted a water boiling test, which is a simplified simulation of the cooking process under household conditions. This test analyzes the ignition/flame initiation of the briquettes, and determines the thermal efficiency, the power of the flame produced, and the combustion rate. The flame temperature and the time required to bring the water to a boil are also measured.

In our study, to test the combustibility of our charcoals, briquettes produced (from pig manure), we first performed the comparison of their physicochemical parameters to those of wood charcoal usually consumed in Nzérékorétown. As shown in Figure 11, the produced ecological charcoal (charcoal from pig manure) is denser and most humid than the wood charcoal.

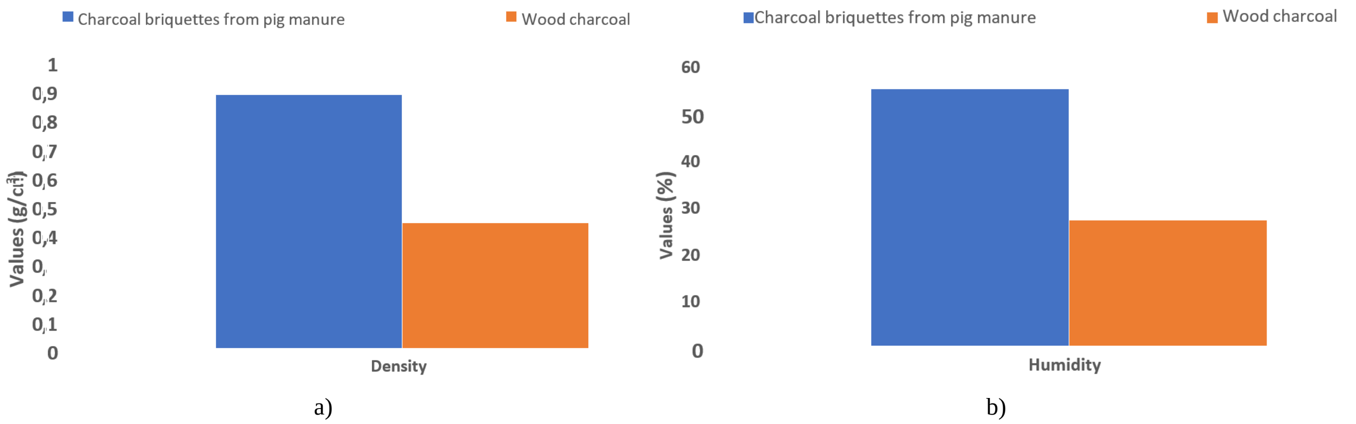

Figure 11. *Comparison of pig manure charcoal and wood charcoal physicochemical parameters, a) density, b) humidity.*

Figure 12. *Combustibility test: comparison between wood charcoal and ecological charcoal produced from pig manure.*

For the second step of the combustibility test, we used two furnaces containing 300 g of wood charcoal one and the second of pig manure charcoal produced. Then two pots of the same type both containing ½ liter of water, were each placed on a furnace before putting then on the fire at the same time with the same initial temperature (Figure 12). We then started a stopwatch to determine the boiling time, temperature evolution of the water in each pot and subsequently determined the heat quantity released by the water during the combustion of each of the two types of charcoal. The total consumption time of the two coals was also determined.

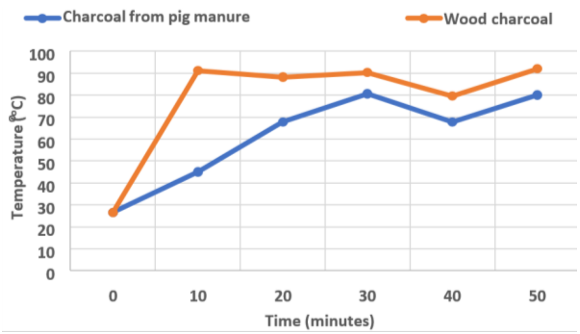

Figure 13. *Temperature evolution of the water: comparison between wood charcoal and ecological charcoal produced from pig manure.*

Figure 13. shows the comparison of temperature evolution of water with time for the two-charcoal type.

Figure 14 illustrates the comparison of temperature diagram variation of water with time for the two-charcoal type.

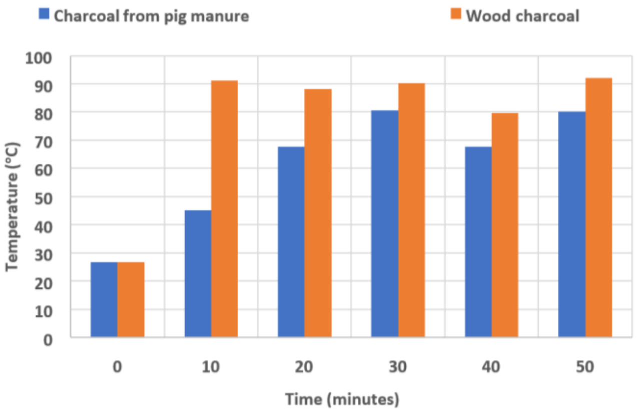

Figure 14. *Temperature diagram variation of the water: comparison between wood charcoal and ecological charcoal produced from pig manure.*

Figure 13 shows the water boiled with wood charcoal reaches its maximum temperature most rapidly than water boiled with ecological charcoal produced from pig manure. This maximum temperature (92 ℃) is reached in 10 minutes for wood charcoal and (92 ℃) in 30 minutes for ecological charcoal (charcoal from pig manure). This slow combustion could be due to the drying rate of the briquettes produced and the dosage of the binder used. However, it may present an advantage for cooking certain types of food. In Figure 14 the same trends is observed, in each time interval, charcoal heated up more rapidly than ecological charcoal (charcoal from pig manure). Using Figure 14, the evolution of the heat quantity released is calculated and represented in Figure 15.

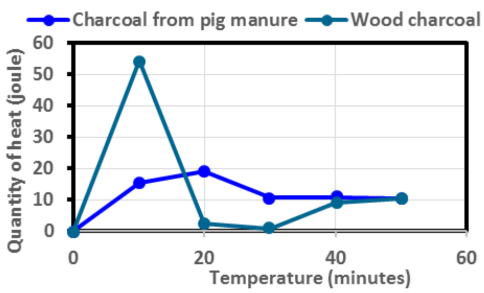

Figure 15. *Heat quantity release by the waters: comparison between wood charcoal and ecological charcoal produced from pig manure.*

As it can be observed the heat quantity curve has linear shape as the temperature evolution curve.

The combustibility test of ecological charcoal from pig manure revealed it is less energic than wood charcoal, that the flame resulting from its combustion was observable and a large quantity of ash was obtained at the end of combustion (Figure 16).

Figure 16. *Ash after total combustion: comparison between wood charcoal and ecological charcoal produced from pig manure.*

4. Conclusions

In this last paper, we developed a new model of ecological charcoal production from pig manure whose different stages of manufacture are: collection of pig manure, transport, weighing, drying, carbonization, crushing, sieving, mixing with addition of binder, compaction to give the shape of the briquettes. Once obtained, the ecological charcoal briquettes were dried in the sun. For 9kg of carbonized black powder, we obtained 120 charcoal briquettes from pig manure. Then a physicochemical characterization of the briquettes produced was performed, the density and humidity rate determined are respectively 0.88g/cm^3 and 54.84%. Finally, we carried out a combustibility test of ecological charcoal produced. To do this, a comparison of the physicochemical properties between our ecological charcoal produced and the charcoal consumed in the N'zérékoré town. We found the produced ecological charcoal (charcoal made from pig manure) is denser and more humid than wood charcoal. We also observed the wood charcoal reaches its maximum temperature most rapidly than water our ecological charcoal produced from pig manure. This slow combustion could be due to the drying rate of the briquettes produced and the dosage of the binder used. However, this kind of combustion may be an advantage for cooking certain types of food.

Abbreviations

V	Briquettes Volume
R	Briquettes Radius
H	Briquette Height
m	Briquettes Mass
Humidity (%)	Humidity Rate

Author Contributions

Oumar Keita: Conceptualization, Resources, Formal

Analysis, Funding acquisition, Investigation, Methodology, Validation, Visualization, Writing - original draft, Writing - review & editing

Madeleine Kamano: Data curation, Validation, Investigation, Resources

Mamady Diakite: Formal Analysis, Software, Investigation, Data curation

Data Availability Statement

The data used or analyzed in this study can be available upon request. Contact the corresponding author if needed.

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Conflicts of Interest

The authors declare no conflicts of interest.

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Biography

Oumar Keita is Professor in the Department of Hydrology at the University of Nzérékoré in Guinea. He completed his PhD in Engineer Sciences, Geomechanics fiels, from Brussels School of Polytechnic, Free University of Brussels (ULB). Belgium. He holds three master's degrees, the first in Modelling and Experimentation in Solids Mechanics (MEMS) at Joseph Fourier University of Grenoble I, France in 2007. The second in Mechanical Engineering, Option, Mechanical Design and Manufacturing at Tunis national school of Engineering, Tunisia in 2003, and the third in Automotive mechanics at Polytechnic institute of Conakry University, Guinea. He has participated in several scientific conferences as a keynote speaker.

Research Field

Oumar Keita: Solar panels performance analyzes under environmental conditions, Biogaz production (from animal dejection), Ecological charcoal production (from agriculture waste, animal dejection), Hydro energy modeling, Wind Energy modeling, Thermal energy modeling

Madeleine Kamano: Biogaz production (from animal dejection), Ecological charcoal production (animal dejection)

Mamadi Daikité: Climate change impact analysis, Renewable energy