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Technical and economic feasibility Analysis for a green coal production unit using millet, maize and cotton stalks in the far North Region, Cameroon

Emilienne Bogwarbe[1,2*], Abed Nimpa Ngoufo[2], Ulrich Tsapi Takua[2]

[1]Department of Renewable Energies, faculty of Sciences (FS) of University of Garoua, Garoua, Cameroon; rectorat@univ-garoua.cm;[2] Enterprise ENERGETIC SOLUTION FOR ALL (ESA), Maroua 2 council, Maroua, Cameroon; contact@esa-services.com

Corresponding author**:** ebogwarbe@yahoo.fr

Abstract. Green coal obtained by carbonizing agricultural residues and biodegradable household waste, is one of the innovative solutions currently being used in several countries to tackle deforestation. The aim of this work is to study the technical and economic feasibility for a green coal production Unit in the far North Region of Cameroun. The objectives are to assess the potential of agricultural residues in the locality, the efficiency of the carbonizer, the thermo-chemical characteristics of the green coal produced and its acceptability by users and the viability of the project. For this purpose, an assessment of the used agricultural residues potential was carried out by the mean of residues/products ratio, then the efficiency of the carbonizer was evaluated by calculations as well as the quality of the green charcoal by compared combustion tests conducted in a small-scale enterprise based in Maroua using a "1-barrel" carbonizer. The acceptability tests were made through survey and the Return on Investment (RI) was used as a parameter to evaluate the profitability of the green coal production unit. The results have shown that (i) the theoretical potential of sorghum/millet, maize and cotton stalks is estimated at 2,688,062.4 tons per year, (ii) the efficiency of the carbonizer varies between 22 and 25% depending of the raw material, (iii) Arabic gum is the binder that gives the best quality to the green charcoal, (iv) the green charcoal can very easily find a market. Nonetheless, the Return on Investment shows a deficit in the manufacturing of green coal. Ways for improvement have been proposed. These include the use of a "3-barrel" carbonizer and the rising of the green charcoal selling price to 500 FCFA.

Keywords. Cameroon; Far North Region; Agriculture residues; Carbonization; Green coal.

1. Introduction

There is no doubt that wood energy is still the main source of cooking energy in developing countries. In sub-Saharan Africa, it accounts for more than three quarters of household energy consumption [1]. Access to this source of energy is becoming increasingly difficult due to the growing number of bans on wood harvesting. In rural areas, collecting firewood is an arduous task, often devolved to women and children, who have to travel ever greater distances to obtain their supplies. In urban areas, the price of firewood and charcoal has risen sharply in recent decades due to the scarcity of the resource, the increase in demand and the distance between production and consumption areas [2]. Moreover, the exclusive use of wood as a domestic fuel has one major drawback, which is deforestation, leading to climate change. An alternative solution therefore needs to be found to the use of wood as domestic energy. One solution consists of recovering agricultural residues or renewable biomass that cannot be recycled and transforming them into green coal briquettes that are used in the same way as wood coal [3].

Green coal is one of the innovative solutions currently being used in several countries. It can be produced locally from all kinds of organic waste through carbonization process. Although people, especially in desert areas, have a strong culture of recycling agricultural residues, carbonization offers the advantage of improving the thermal properties, such as calorific value and smoke-producing power, of these residues [4]. Many associations, cooperatives and young green entrepreneurs have started to produce this plant-based fuel as an alternative energy source.

Several production units have been set up in various parts of Cameroon, including Garoua and Lagdo in the North Region, Maroua and Mokolo in the Far North Region. However, the majority of green coal producers have embarked on this activity without any technical knowledge or entrepreneurial spirit. To guarantee the long-term future of production units, production must be profitable for the company and meet the interest of consumers, which in this case, is the good quality of the green coal.

The aim of this study is to assess the technical and economic feasibility of producing green coal with a view to proposing strategies for improving the process. Specifically, the aim will be to assess the potential of the agricultural residues (millet, cotton and maize stalks) that constitute the raw material, to evaluate the performance of the carbonizer and assess the quality of the green coal as well as its acceptability to the user populations, to analyze the economic viability of the unit and to propose an optimization given that the process of manufacturing and selling green coal shows great variability depending on the production context [11]. This is still an innovative process for which there are no clear benchmarks and for which it is important to define the criteria to be taken into account to facilitate the success of this type of project.

2. Material and Methods

The current study was carried out based on a small-scale briquetting enterprise located in Maroua-Cameroon operating with agricultural residues, including millet, sorghum, maize and cotton stalks.

2.1. Materials

2.1.1. Study area. The Far North Region is one of the ten regions of Cameroon created by Presidential Decree n°83/392 of 22 August 1983 following the break-up of the former Northern Province into 03 provinces and covered a surface area of 34 262 km^2 with Maraoua as head-quarter. It lies between the 10th and 13th Latitudes North and the 13th and 15th Longitudes East. Located in the north of the country and bordering Chad and Nigeria, the Far North Region comprises six (6) Divisions, forty-seven (47) Sub-divisions and forty-seven (47) councils. Figure 1 shows the map of the region.

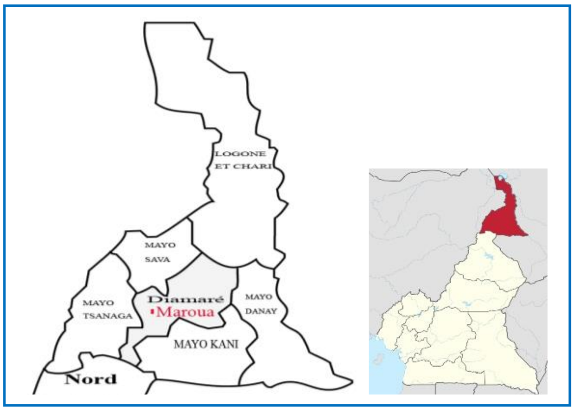


Figure 1: Map of the Far North Region of Cameroon

Its population was estimated at about 4 ,186, 844 people in 2017. It has a Sudano-Sahelian climate with two seasons: a dry season lasting seven months (October-April) and a rainy season lasting five months (May-September). Minimum temperatures are recorded in January and December and are between 25°C and 27°C while maximum temperatures are recorded in April and May and are between 38°C and 42°C. Over a period from 1950 to 2015, the average total annual rainfall is 863.2 mm, with an average number of rainy days in a year of 71 days [5].

Hydrologically, this Region is dependent on two major basins: the Lake Chad basin (which constitutes the largest endoreic unit on the African continent) and the Benoué basin. All the rivers in the Region are characterized by non-permanent flows.

Agriculture in the Region is mainly based on cereals, pulses, vegetables and fruit. Cotton is the only cash crop grown in the region.

2.1.2. Agricultural residues. The residues used consists of maize, cotton and millet stalks as presented in figure 2 below.

(a) (b) (c)

Figure 2: Agricultural residues: (a) Maize stalks; (b) Cotton stalks; (c) Red millet stalks

2.1.3. Binder. Four types of binder were used to bind the green coal powder: cassava starch, Arabic gum, cow dung and clay.

2.1.4. Carbonizer. A "1-barrel" carbonizer provided with a cover and a chimney to enable drawing out the smoke as shown in figure 3 served for the purpose; it has a capacity of 0.2 m3 (90 cm of Height and 55cm of diameter) and small openings are made at its bottom.

Figure 3: "1-barrel" carbonizer

2.1.5. others materials. An analytical balance, a thermometer, a manual agglomerator, a simple dryer (metal sheet), an electric grinder, a manual mixer, a manual compactor, a barbecue, two kettles, two buckets, a shovel, a tricycle and survey sheet.

2.2. Method

2.2.1. Residue's potential assessment. It is absolutely essential, before green coal production project, to assess the quantity of raw material that can actually be available, its regularity and its availability. The theoretical potential of the different agricultural residues was considered in this work. The theoretical potential corresponds to the quantity of residues theoretically produced in the locality. It is calculated using mathematic models proposed by Okello and al. [6] and Mboumboue & Djomo [7] taking into account the average yield of the plantations and the residue/product ratios.

$$(CR)_i = (RPR)_i \times (P_rC)_i \quad (1)$$

The energy potential of biomass briquettes made from each residue is calculated based on the following equation:

$$(EnR)_i = (CR)_i \times (\mathrm{LHV})_i \times (MR)_i \quad (2)$$

where $(CR)_i$ is the amount of each agricultural biomass residue, $(RPR)_i$ the Residue-to-Product Ratio of each residue, $(P_rC)_i$ is the annual amount of each crop production, $(\mathrm{LHV})_i$ is the Low Heat Value of biomass briquettes, $(MR)_i$ is the mass ratio of briquettes produced to briquetting residues, $(EnR)_i$ is the biomass briquette energy potential from each residue. The $(P_rC)_i$ values for 2018 were reported by [8] for the millet, sorghum, maize and [9] for cotton. The $(RPR)_i$values of all the residues and the Low Heat Value of biomass briquettes from each residue were carried out by several studies and reported in the literature; $(MR)_i$ values were found in [10].

2.2.2. Green coal production process. The process of production of green coal comprises many steps as shown in figure 4 below.

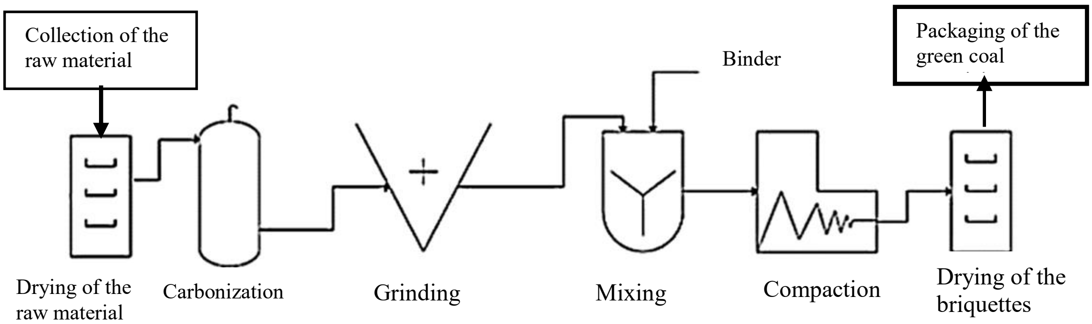


Figure 4: Green coal production process [11]

- Collection of the stalks. The millet, maize and cotton stalks are collected by the mean of a tricycle from the farms to the briquetting area.
- Drying of stalks collected. The aim is to remove the water from the waste to make the pyrolysis more efficient. This is done at ambient temperature (28–38 °C) for 1 or 2 days.
- Carbonization. The aim of carbonizing is to induce the chemical decomposition of the residues by the action of heat in order to obtain a product composed mainly of carbon. The method used in this study is carbonization by partial combustion. In this technique, the energy required for carbonization is provided by the combustion of part of the charge, placed inside the carbonizer. The raw materials are broken in pieces of 15 cm to facilitate the carbonization. At the beginning of the process, the cover is removed of about 15 minutes to let volatile gases move out. The cover is then replaced and well-sealed to avoid entrance of air. The time of carbonization depends on raw biomass materials chosen. The efficiency of the carbonizer is calculated by the relationship:

$$\eta = \frac{\text{Mass of green coal produced}}{\text{Mass of raw material used}} \qquad (3)$$

- Crushing.
  The carbonized material is grinded into fine particles of less than 5 µm in order to achieve good quality mixing and compaction. Grinding is done by the mean of an electrical grinder.
- Mixing.
  The mixing of crushed materials is done by the addition of binder in clearly-defined proportions, which leads to the facilitation of briquetting. A lot of binders could be used depending on physicochemical characteristics, availability in the local market and low price. In this study, four binders were tested (starch, okra stem gum, cow dung, clay) and pre-tests have been done to find out the good proportion. The material used is a manual mixer.
- Compaction.
  Compaction technique is pelletizing. The coal powder mixed with a binder are transformed into balls or pellets using a manual press.
- Drying of briquettes produced.
  The molded briquettes are finally dried in order to produce them in a dehydrated form. They are dried in open air at an ambient temperature of 28 °C to 38°C for 2 or 3 days.
- Packaging.
  The green coal is packaged in plastic bags at the weight of 0.5 kg as shown by figure 5.

Figure 5: Packages of green coal

2.2.3. Combustion Test. The aim of the test is to appreciate de combustion of the green coal produced. It consists of water boiling test which is a simplified simulation of cooking process in household utilization conditions: In open air, 500 g of green coal is place into a barbecue; after ignition, a kettle containing 1 l of water at room temperature is placed on the barbecue and visual evaluations of the smokes, ashes and odor are also made. The same data obtained with 500 g of charcoal is used as a reference.

2.2.4. Acceptability test. A survey was carried out in Maroua. Its main objective was to study the population's acceptance of briquette and to assess the market potential for fuel briquettes. For this end, 5 small restaurants and 20 households were interviewed.

2.2.5. Economic analysis. The objective of the conducted economic analysis is to estimate the cost of production of briquettes made from the tree crop residues selected and to determine the profitability of the business. The profitability calculation is made on the basis of the cost of investment, the cost of production and revenues. The Return on Investment (RI) was used as a parameter to evaluate the profitability of the green coal production unit. The shorter the payback period, the more attractive is the investment. It is calculated by the following formula:

$$\text{Payback Period (PbP)} = \frac{\text{Investment Cost}}{\text{Profit}} \tag{4}$$

However, other criteria such as cash flow or net present value must also be taken into account for a complete analysis.

3. Results and Discussion

3.1. Results of technical analysis

3.1.1. Theoretical Potential of the crop residues. Table 1 presents a summary of the estimated annual amount of biomass briquettes derived from agricultural residues investigated as well as the energy potential. The results show that the annual crop stalks production in the far North region is 2,688,062.4 tons and the briquetting conversion of these residues could produce 821,004.72 tons of biomass briquettes. The total biomass briquette energy potential from the residues chosen is 14,567.35 TJ per year. Among the investigated residues, sorghum stalks are likely to produce briquette with the highest energy potential of 8,296.66 TJ per year, followed by maize and cotton stalks with 3,198.53 TJ per year and 2,809.41 TJ per year respectively. This is due to the high annual production of sorghum (about 800 thousand tons). These results are contrary to the results obtained by [12] who estimated that the residues potential is dominated by maize in the far Region. This is surely due to the non-consideration of sorghum/millet in the study. Figure 6 shows the energy potential of briquettes from each residue.

Table 1: Estimated amount of biomass briquettes derived from crop stalks and energy potential

crops	Annual production (t)	Type of residue	RPR	Amount of residues (t)	MR	Amount of briquettes (t)	LHV briquettes (MJ/Kg)	E. potential (TJ)
Millet	24,602.00	stalks	2.00	49,204.00	0.30	14,761.20	17.8	262.75
Sorghum(ds)	261,593.10	stalks	2.00	523,186.20	0.30	156,955.86	17.8	2793.81
Sorghum (rs)	515,248.20	stalks	2.00	1,030,496.40	0.30	309,148.92	17.8	5502.85
maize	299,487.90	stalks	2.00	598,975.80	0.30	179,692.74	17.8	3198.53
cotton	130,000	stalks	3.74	486,200	0.33	160,446.00	17.51	2809.41
Total	**1,230,931.20**	-	-	**2,688,062.4**	-	**821,004.72**	-	**14567.35**

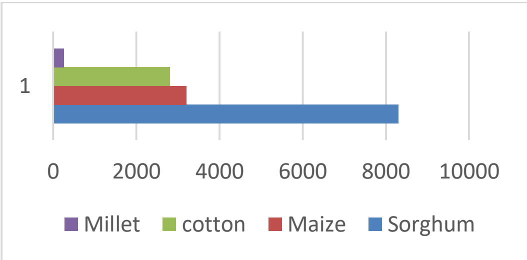


Figure 6: Estimated energy potential of briquettes from each residue (TJ/year)

3.1.2. Carbonization time and efficiency. Figure 7 highlights the variation of carbonization time and efficiency according to the type of residues. The carbonization time recorded are 2h 02 min, 2h 30 min and 1h 56 min for sorghum/millet, cotton and maize respectively. The carbonization time of maize stalks is shorter than that of sorghum/millet and cotton stalks. A carbonization time of 3 h 20 min for Typha and 1 h 02 min for rice husk was obtained by [13] and [3] respectively. This difference may be due to the tightness, the size and the moisture content of the raw material.

The efficiency of carbonizer is 23%, 25 % and 22% for sorghum/millet, cotton and maize respectively. The carbonization efficiency is practically the same as that obtained by [13] for Typha (24.3%) in a "3-barrel" carbonizer. On the other hand, this efficiency is higher than that found by [14] which is 10% for organic matter (paper and cardboard) in a similar carbonizer. Values of 30% and 33% for sorghum/millet/maize and cotton respectively were reported in [10]. It can be seen that carbonization of cotton yields the best efficiency. This can be explained by the higher moisture content of cotton stalks (12%) compared at that of the maize (11.11%).

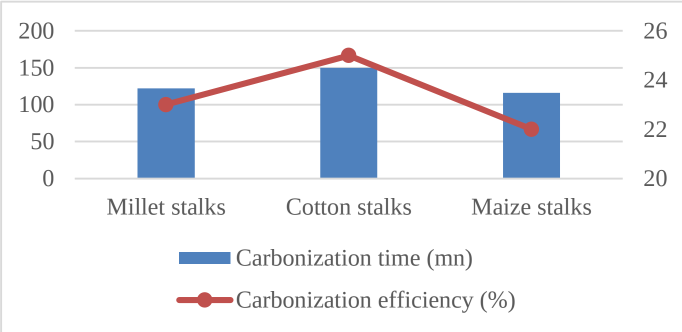


Figure 7: carbonization time and efficiency according to the type of residues

3.1.3. Compaction. Figure 8 shows the Coal powder obtained after crushing of the carbonized material and briquettes of green coal. The binders were used in the proportions given in Table 2 below in application of THEAU *and al.* [2] indications.

(a) **(b)**

Figure 8: (**a**) Coal powder obtained after carbonization and crushing of the raw material;

(**b**) Briquettes of agglomerated green coal.

Table 2: Proportion of green Coal Constituents

Type of Binder	Quantity of Green Coal Powder	Quantity of Binder	Quantity of Water
Starch	64.5%	3.2%	32.3%
Gum Arabic	65.4%	5.2%	29.4%
Cow dung	63.5%	6.3%	30.2%
Clay	60.6%	7.6%	31.8%

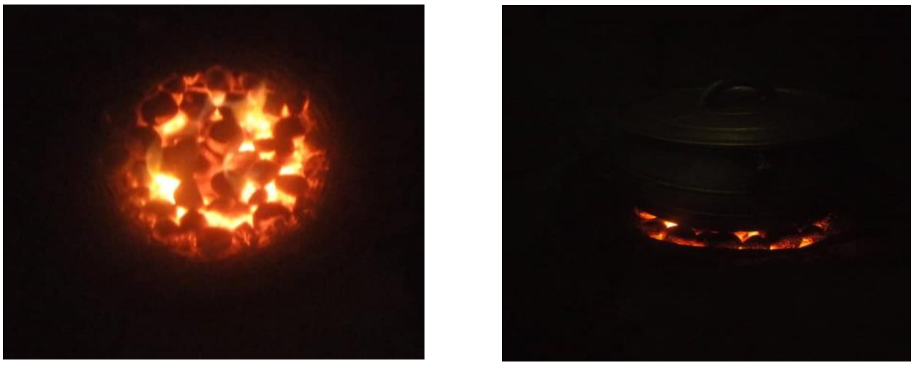
3.1.4. Effects of binders. Table 3 below shows the advantages and disadvantages of each type of binder. Based on a hand pressure assessment, the green coal molded with Arabic gum is the strongest, followed by the one molded with starch, then the one molded by cow dung and finally the one bounded by clay. The last position occupied by clay can be justified by the diversity of its quality. It is likely that the one used in this experiment is not the best or the proportion of the binder is not adequate. In general, coal molded with inorganic binder are more resistant to compression than that molded with organic binder [12].

It can be seen from the table 3 that the use of cow dung and clay offer the less price of the green coal, followed by the starch. But Arabic Gum is the binder that offers a better quality of the green coal, so it will be retained for the rest of the study despite the fact that it would contribute to increasing the cost price of the green coal.

Table 3: Advantages and disadvantages of each type of Binder

Binder	Availability	Mass percentage in the green coal (%)	Solidity of pellets	Cost Price (FCFA/kg)	Part of Binder price in price of green coal FCFA/kg)
Starch	Scarce	3.2	+ + +	300	9.6
Arabic Gum	Easy	5.2	+ + ++	350	18.2
Cow dung	A bit scarce	6.3	+ +	0	0
Clay	A bit scarce	7.6	+ +	0	0

3.1.5. Combustion test. Combustion tests were carried out in order to compare the different samples produced, with the wood coal boiling test being the reference. The experiment setup is featured in figure 9.



(a) **(b)**

Figure 9: (a) Green coal ignition; **(b)** Boiling Test device.

Table 4 features the results of the comparative study of cooking conditions for green coal and wood coal. It is shown that Arabic Gum offers the best cooking conditions. The ignition is very easy in this study and this result is contrary to the result obtained by Senchi and Kofai [15] who have produced briquettes made up of a mixture of rice husk and charcoal powder and molded with Arabic gum. The ignition time ranged between 36 à 45 minutes and this was attributed to Arabic Gum used as binder. This situation could find an explanation in the proportion of the binder and the compaction technique. The briquettes manually molded are less compact than those which are molded with a mechanic press, so their ignition will be easy.

Table 4: Comparatives cooking conditions

Type of coal	Ignition	Smoke	Ash	Odor	Reusability
Wood coal	Easy	A little	A little	No	Yes
Green coal/starch	Easy	No Smoke	A little	No	Yes
Green coal /Gum Arabic	Very easy	No Smoke	A little	A little	Yes
Green coal /cow dung	A little difficult	A lot of Smoke	A lot	A little	No
Green coal / clay	Difficult	No Smoke	A little	No	No

3.1.6. Water boiling test. Depending on the binder chosen, the boiling time and boiling period vary. Figures 10 and 11 provide an overview of the boiling time and boiling period with respect to the binder. It can be seen from figure 7 that clay offers the best time both in terms of the boiling time and period.

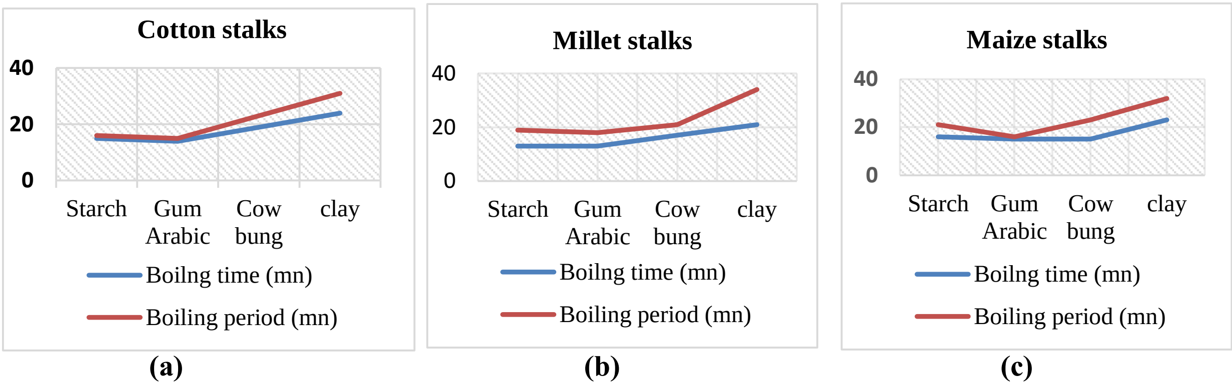
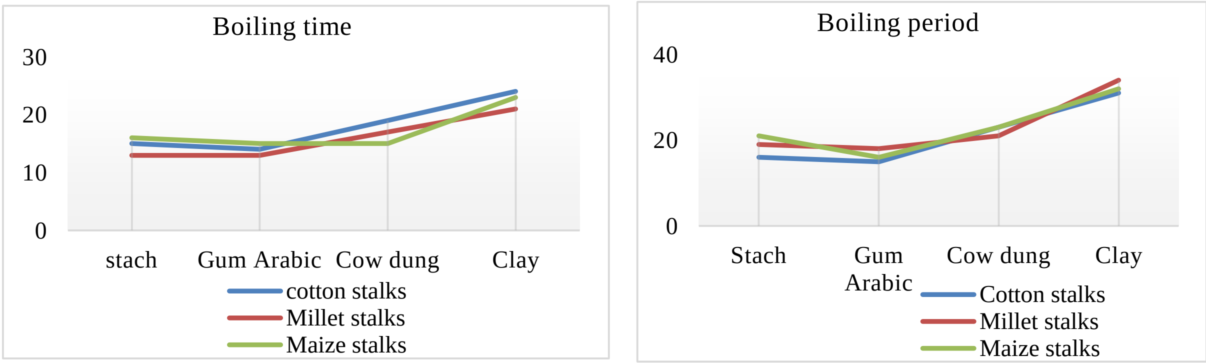


Figure 10: Boiling time and boiling period with respect to the binder: (a) for cotton stalks; (b) For millet/sorghum stalks; (c) for maize stalks.

For the starch and the Arabic Gum, the boiling time for millet/sorghum stalks is shorter than that for the other two residues. The boiling period follows a similar variation for starch, but in the case of Arabic gum, maize stalks last the least. For the cow dung, Maize stalks offer the lowest boiling time while the least boiling period is recorded by millet stalks. In the case of clay, the situation is inverted while the maize stalks remain in the same position.

It can be noted that the boiling time for all types of crop stalks and binder is less than or equal to that of charcoal, which is 23 minutes. However, the boiling is maintained in all cases for more than 15 minutes for each briquette, some even reaching 30 minutes much higher than that of charcoal which is 20 minutes. The cooking time was reported shorter. This result shows that the Low Heating Value (LHV) of the green coal is greater, approximately equal to that of wood coal.



(a) **(b)**

Figure 11: Comparative **(a)** boiling time with respect to the binder; **(b)** boiling period with respect to the binder.

3.2. Results of economic analysis

3.2.1 Acceptability Tests. The results of the acceptability tests carried out on 5 small restaurants and 20 households showed that the green coal produced can very easily find its market despite some disadvantages related to the type of binder used and which are shown in table 4. Despite these disadvantages, it has received 90% acceptability, i.e., 90% of the households surveyed are willing to use this fuel as their main fuel mainly because of its lower cost (33% of the wood coal price). Akowah *and al.* [16] conducted a similar study in Ghana in 2012 and the results shown that 93% of the households interviewed are favorable to the use of green coal provided its selling price is comparable to that of charcoal. Mathilde Laval also conducted a study on green coal in southern countries in 2014 [1] and the results shown that green coal could be considered as a new source of cooking energy for under-developed countries households in the case that the cost of green coal is relatively less than that of wood charcoal.

3.2.1 Calculation of Return on investment (RI). The financial capacity of producers is very low, they cannot afford modern tools for green coal production. So, the Evaluation of profitability is based on the following assumptions:

Scenario 1:

- Usage of "1-barrel" carbonizer
- 10 months worked per year, given the difficulties related to the rainy period of July and August;
- 04 operators are involved in the production chain;
- 24 days worked per month, equivalent to 6 days per week;
- Production and sale of 16.8 kg of green coal per day;
- Selling price of 1 kg of green coal is set at 200 FCFA (equivalent cost of wood coal = 600 FCFA/kg).

Scenario 2:

- Usage of "1-barrel" carbonizer
- 10 months worked per year, given the difficulties related to the rainy period of July and August;
- 04 operators are involved in the production chain;

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- 24 days worked per month, equivalent to 6 days per week;
- Production and sale of 16.8 kg of green coal per day;
- Selling price of 1 kg of green coal is set at 500 FCFA (equivalent cost of wood coal = 600 FCFA/kg).

Scenario 3:

- Usage of "3-barrel" carbonizer
- 10 months worked per year, given the difficulties related to the rainy period of July and August;
- 04 operators are involved in the production chain;
- 24 days worked per month, equivalent to 6 days per week;
- Production and sale of 50.4 kg of green coal per day;
- Selling price of 1 kg of green coal is set at 500 FCFA (equivalent cost of wood coal = 600 FCFA/kg).

Tables 5 to 10 show the cost of investment and production of the green coal production unit in Maroua and table 11 the profitability index.

Table 5: Cost of Investment for scenario1

Item	Quantity	UP (FCFA)	TP(FCFA)	Lifespan (year)	Depreciation
Carbonizer	1	20 000	20 000	3	6 667
Tricycle	1	1450 000	1 450 000	5	290 000
Shovel	1	2 500	2 500	1	2 500
Dryer	5	6 500	32 500	5	6 500
Electric shredder	1	350 000	350 000	5	70 000
+Digital balance	1	10 000	10 000	3	3 333
Manual mixer	1	200 000	200 000	5	40 000
Manual compactor	1	35 000	35 000	3	11 667
Containers	2	1 500	3 000	2	1 500
Pot	3	6 000	18 000	10	1 800
Barbecue	1	3 500	3 500	3	1 167
Thermometer	1	55 000	55 000	5	11 000
Total investment			**2 179 500**	**Total depreciation**	**446 134**

Table 6: Cost of production for scenario 1

Section	Quantity	UP (FCFA)	TP(FCFA)	Cost per Kg of green coal
Depreciation	1	446 134	446 134	110.6
Maintenance (5% of Investment)	0.05	2 179 500	108 975	27
Manpower	4	200 000	2 000 000	496
Other expenses (water, fuel, packaging, Binder, etc)	1	650 400	650 400	161.3
Total production cost			**3 205 509**	**794.9**
Sales figures			**806 400**	**200**
Profit/loss			**-2 399 109**	**-594.9**

Table 7: Cost of Investment for scenario 1

Item	Quantity	UP (FCFA)	TP(FCFA)	Lifespan (year)	Depreciation
Carbonizer	1	20 000	20 000	3	6 667
Tricycle	1	1450 000	1 450 000	5	290 000
Shovel	1	2 500	2 500	1	2 500
Dryer	5	6 500	32 500	5	6 500
Electric shredder	1	350 000	350 000	5	70 000
Digital balance	1	10 000	10 000	3	3 333
Manual mixer	1	200 000	200 000	5	40 000
Manual compactor	1	35 000	35 000	3	11 667
Containers	2	1 500	3 000	2	1 500
Pot	3	6 000	18 000	10	1 800
Barbecue	1	3 500	3 500	3	1 167
Thermometer	1	55 000	55 000	5	11 000
Total investment			**2 179 500**	**Total depreciation**	**446 134**

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Table 8: Cost of production for scenario 1

Section	Quantity	UP (FCFA)	TP(FCFA)	Cost per Kg of green coal
Depreciation	1	446 134	446 134	110.6
Maintenance (5% of Investment)	0.05	2 179 500	108 975	27
Manpower	4	200 000	2 000 000	496
Other expenses (water, fuel, packaging, Binder, etc)	1	650 400	650 400	161.3
Total production cost			**3 205 509**	**794.9**
Sales figures			**2 016 000**	**500**
Profit/loss			**-1189509**	**-294.9**

Table 9: Cost of Investment for scenario 3

Item	Quantity	UP (FCFA)	TP(FCFA)	Lifespan (year)	Depreciation
Carbonizer	3	60 000	60 000	3	20 000
Tricycle	1	1450 000	1 450 000	5	290 000
Shovel	1	2 500	2 500	1	2 500
Dryer	5	6 500	32 500	5	6 500
Electric shredder	1	350 000	350 000	5	70 000
Digital balance	1	10 000	10 000	3	3 333
Manual mixer	1	200 000	200 000	5	40 000
Manual compactor	1	35 000	35 000	3	11 667
Containers	2	1 500	3 000	2	1 500
Pot	3	6 000	18 000	10	1 800
Barbecue	1	3 500	3 500	3	1 167
Thermometer	1	55 000	55 000	5	11 000
Total Investment			**2 219 500**	**Total Depreciation**	**459 468**

Table 10: Cost of production scenario 3

Section	Quantity	UP (FCFA)	TP(FCFA)	Cost per Kg of green coal
Depreciation	1	459 468	459 468	38
Maintenance (5% of investment)	0.05	2 219 500	110 975	9.2
Manpower	4	200 000	2 000 000	165.3
Other expenses (water, fuel, packaging, Binder, etc)	3	650 400	1 951 200	161.3
Total production cost			**4 521 643**	**373.8**
Sales figures			**6 048 000**	**500**
Profit			**1 526 357**	**126.2**

Table 11: Profitability Index

N° scenario	Cost of investment (FCFA)	Profit/loss (FCFA)	Return On investment
1	2 179 500	-2 399 109	-0.9 an
2	2 179 500	-1189509	-1.8 an
3	2 219 500	1526357	1.45 an

The results contained in table 11 show that the payback period of scenario 1 and 2 are negative, which means that the company will never recover its initial investment. Instead, it will continue to lose money each year for 0.9 year and 1.8 years respectively. So, the project with scenario 1 and 2 are not economically viable for the company while the payback period of scenario 3 is equal to 1.45 year meaning that the company will recover its initial investment in approximately 1 year and 5 months. Sengar *and al.*[17] reported payback periods of 0,68 and 0,63 year respectively for cashew nut and grass briquettes. Hamid *and al.* [18] reported a payback period of 2 years for rice husk more than the payback period of 1.3 reported by [19] for the same residues.

The cost price of charcoal in Maroua is indeed 600 FCFA. The selling price of green coal was fixed based on the motivation of the producers to attract customers without a preliminary study. Green coal consumption is almost the same as that of the Wood coal consumption, and this fact would have been taken into account when working out the market price for green coal.

4.**Conclusion**

The aim of this study was to realize technical and economic analysis of green coal production in the far north region. This study shows the relevance of the strategy of converting agricultural residues into green charcoal in a context where domestic fuels are becoming scarce and expensive. The technical analysis has shown that raw materials are sustainably available (more than 2,688 Kt per year**)** and the briquettes molded with Arabic gum as binder offer the best cooking conditions despite its high cost. Economically, the green charcoal can very easily find a market with an acceptance percentage of 90% but the selling price (200 FCFA/kg) which is still being practiced cannot permit the company to recover its initial investment even if the production process is optimize by the use of a "3-barrel" carbonizer because of the negative payback period (- 0. 9 year). As green coal consumption is almost the same as that of the Wood coal consumption, this fact will have to be taken into account when working out a market price for green coal. Green coal is considered as a new source of cooking energy for households in under-developed countries. The difficulties facing the sector today call for the rapid establishment of the units in order to improve the population's access to domestic fuels. Nevertheless, the production of green coal in large scale needs important investment and this constitute an obstacle for the development of production units.

Glossary

MINADER	Ministry of Agriculture and Rural Development
DESA	Surveys and Agricultural statistics Directorate
PERACOD	Program for the promotion of Renewables Energies, Rural electrification and sustainable supply of domestic fuel
LHV	Low Heating Value
Kt	Kilo ton
UP	Unit Price
TP	Total Price
FCFA	Franc for African Financial committee
ESA	Energetic Solution for All
TJ	Tera joules

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