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RESEARCH ARTICLE

PRODUCTION OF ECO-FRIENDLY CHARCOAL WITH HIGH ENERGY EFFICIENCY "CHACHAKAN" FROM TYPHA AUSTRALIS AND COCONUT SHELLS

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ABSTRACT

In Africa, traditional fuels are mainly used for cooking meals. In developing countries, most mainly use firewood and charcoal. In Benin, biomass essentially represented by firewood and charcoal represents 55.1% of final energy consumption in 2020. The negative effects of the exploitation of wood energy for the production of charcoal on environment are now well known: pockets of desertification, soil erosion, climate change, etc. These effects can be measured by the increase in charcoal consumption, which depends on household size, dietary habits and also the type of stove used. This study, using the standard process for the manufacture of ecological coal, proposes ecological coals with high energy efficiency called "ChachaKan" made from two kinds of biomass which are: Typha Australis and coconut husks capable of suitably replacing charcoal wood and firewood. These analyzes revealed a sample of charcoal briquette, with a lower calorific value (LCV) of 5,289.98 Cal/g, or 72% of the LCV of the charcoal. The latter has a flammability time of 3 minutes 2 seconds.

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INTRODUCTION

In most Third World countries, biomass energy is the main source of energy for households, around 70 to 90% of the final energy balance depending on the country. Recent estimates from the FAO and the World Bank show that biomass will continue to play a major role in developing countries, particularly in rural areas (1). It is clear that biomass energy plays an important role in meeting basic energy needs for cooking and heating. There are three types of biomass thermal conversion technologies which are direct combustion (2), pyrolysis (3) and gasification (4). In Benin, direct combustion is a widely used technology to produce biofuels due to its simplicity, convenience and low cost. This uncontrolled use of wood for cooking and heating leads to environmental degradation. In the particular case of Benin, for example, the estimates of the environmental action plan of June 1993 reveal that the forest is shrinking on average by 100,000 ha per year (5, 6). To improve the situation, the solutions implemented are: reforestation and energy crops, the popularization of high energy efficiency stoves, the improvement of the efficiency of coal wheels and the substitution of charcoal by alternative fuels. Despite the different solution approaches to solving this problem, biodiversity is under pressure and the evolution of the demand for wood energy is greater than the annual forest formation.

Several countries have agreed to restore interest in prices as an instrument of a sustainable energy policy, by rightly internalizing environmental costs in the economic value of the wood resource in relation to its opportunity cost, for substitutions to LPG (butane gas) or kerosene or other alternative fuels. Other countries have at some point chosen to subsidize fuels and alternatives so that their transfer prices compete with firewood. In order to preserve forests, energy-efficient eco-charcoal emerges as a sustainable alternative to charcoal/firewood, and reduces the tree felling and bush fires. For several years, many studies have been carried out on the production of charcoal briquettes from various types of agricultural waste: including coconut shells (7), sugar cane bagasse and cassava rhizomes. (8), coconut husks, sawdust, rice husks and coffee pods (9), water hyacinth (10), bagasse and clay (11), neem wood residues (Azadirachta indica) (12), eucalyptus wood (13), Madan wood and coconut (14). Unfortunately, very few works have led to real coals with high energy efficiency capable of suitably replacing charcoal; this requires optimization in terms of dosages according to the raw materials present. In this publication, we propose an ecological carbon with high energy efficiency from Typha Australis and coconut shells.

MATERIALS AND METHODS

Two main raw materials are used in this document, in addition to the binder and other secondary raw materials such as water. Typha Australis, also called "chacha" in Mina, is an herbaceous plant of the *Typhaceae* family, available in very sufficient quantities, and which litters the edges of the waterways of the Porto-Novo lagoon in the Oueme than Lake Aheme in Mono. It invades waterways and prevents all river activity (fishing, navigation, etc.). In Benin, some women use it for making mats, in very small proportions compared to the availability of the raw material (in terms of area), even if this has not yet been quantified. Similarly, the waste generated by the use of these mats is not recovered. On the other hand, coconuts, on the other hand, are thrown away by farmers, processors and consumers, and thus constitute a source of environmental pollution. In view of the harmful effects of these two materials on the environment, and their availability in considerable quantities and taking into account their energy potential, it is preferable to use them with a view to cleaning up the living environment and drawing better profit via energy recovery in order to meet a recurring need in the rural world.In addition, we chose clay as a binder because it is commonly used in most combustible briquettes in the literature not only because of its radiating effect which restores the heat stored during the combustion of the biofuel, but also and above all for its availability and very affordable cost.

Figure 1. Typha Australis along Lake Ahémé

Figure 2. Stock of coconut shells

Figure 3. Stock of clay

The equipment used for the production of energy-efficient ecological coals basically consists of an analog scale, a carbonizer, a grinder and a hydraulic click press.

Carbonizer | **Grinder** | **hydraulic clickpress** | **Analog scale**

Table 1. Characteristics

Thermal characteristics	Physico-chemical characteristics
• Ignition time • Boiling time of a liter of water • Fuel Consumption • Controlled Kitchen Test (TCC)	• Water content • Ash content • Lower Calorific Value

The diagram below explains the process of making green charcoal.

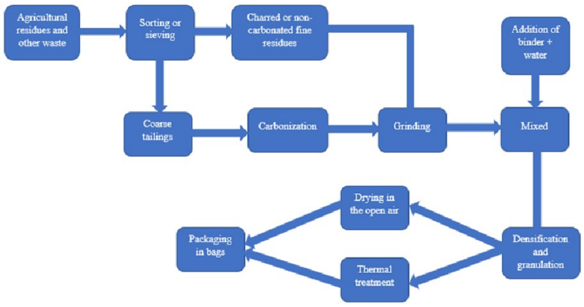


Figure 5. Production process of charcoal briquettes

Five (5) samples of charcoal briquettes were the subject of this study. These samples are composed according to the proportion of the raw materials involved. The samples are identified by means of a coding as indicated in the table below.The determination of the PCI was carried out in the physico-chemical characterization laboratory of the Onigbolo cement works. The ash content was determined according to standard NF EN ISO 18134-3 (15) at the Chemical and Process Engineering Laboratory (GCP) of the Polytechnic School of Abomey-Calavi (EPAC). The humidity rate was determined according to standard AFNOR NF EN 1860-2 (16) at the Chemical and Process Engineering Laboratory (GCP) of the Polytechnic School of Abomey-Calavi (EPAC).

RESULTSAND DISCUSSION

After obtaining the various samples of ecological coals, several tests were carried out to judge their quality. The figure below shows the solid biofuels obtained, while Table 3 shows the results obtained from the combustion tests. The ignition times obtained in the present study are between 1.41 minutes and 5.46 minutes, while the work carried out by JM. Onchieku et al. in 2012 for the production of biochar from sugar cane bagasse and clay exhibited an ignition time ranging from 4.40 to 15.20 minutes (11). The figures (Figure 7 & Figure 8) below show respectively the comparative graphs of the ignition and boiling times, as well as the quantities of fuel consumed present study are between 8 minutes and 16 minutes while those obtained by Ramaroson et *al.* in 2015 (17), MS. Dusabe in 2014 (18), and HK. Abbo in 2014 (19) are between 10 minutes and 21 minutes.

Table 2. Codification of samples of ecological coals produced

N°	Code	Clay (%)	Coconut shells (%)	*Typha Australis* (%)	Paper mache (%)	Meaning of the codes
1	TA-90	10	0	90	0	Charcoal briquette containing 10% CLAY and 90% TYPHA
2	CA-90	10	90	0	0	Charcoal briquette containing 10% CLAY and 90% COCO
3	CTA-6030	10	60	30	0	Charcoal briquette containing 10% CLAY, 60% COCO and 30% TYPHA
4	CP-70	0	70	0	30	Charcoal briquette containing 30% PAPER MACHE and 70% COCO SHELL
5	TP-70	0	0	90	30	Charcoal briquette containing 30% PAPER MACHE and 70% TYPHA

Figure 6. Samples of ecological coals

Table 3. Thermal Parameters

Fuels	Ignition time	Water boiling time	Amount of fuel consumed (g)	Smoke Release
Wood charcoal (witness)	5 min	15 min	233	No smoke
TA-90	5 min 28 s	11 min 41s	250	No smoke
CA-90	1 min 45 s	12 min 7 s	170	No smoke
CTA-6030	3 min 2 s	12 min	220	No smoke
TP-70	1 min 41 s	16 min 6 s	250	No smoke
CP-70	1 min 46 s	8 min 53 s	110	No smoke

Table 4. Results of the controlled combustion Tests (CCT) of the CTA-6030 ecological coals

CTA-6030 ecological coals				
Food	Amount of food (g)	Fuel used (g)	Fuel consumed (g)	Cooking time
Rice	265	570	355	13 min 56 s
Beans	205	1040	470	59 min 48 s
Bambara Groundnut	205	1365	1310	3 h 46 min 58 s

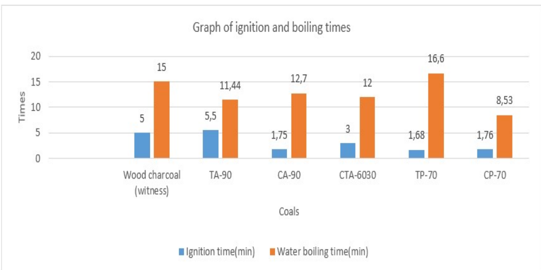
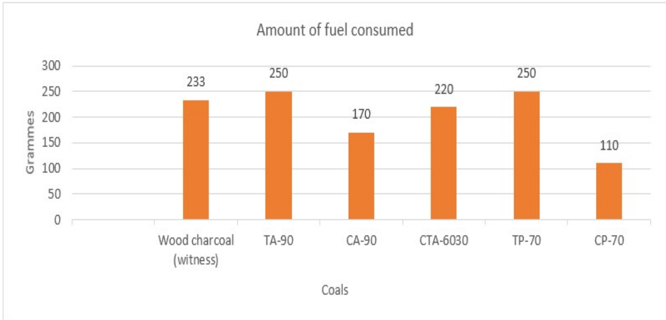


Figure 7. Comparative graph of ignition and biling times

Graph 7 shows that the ignition time of ecological charcoal TA-90 omposed of (*Typha Australis* + clay) is about 5min30s: this value is close to that of charcoal which is around 5 minutes. The ignition times of ecological coal CTA-6030, composed of (coconut shells+*Typha Australis*+clay) on the one hand, and CA-90 (coconut shells+clay) are all less than 5 minutes, and are respectively worth 3 min and 1min45s.



Fgigure 8. Comparative graph of the quantities of fuel consumed

Table 5. Charcoal Controlled Combustion Test (CCT) Results

Charcoal				
Foods	Amount of food (g)	Fuel used (g)	Fuel consumed (g)	Cooking time
Rice	265	500	215	11 min 41 s
Beans	205	735	515	56 min 45 s
Bambara Groundnut	205	2500	2115	3 h 35 min 53 s

Tableau 6. Characteristic values of ecological coals

N°	Fuels	Anhydrous LCV (Cal/g)	Humidity W (%)	Ash content (%)
1	Wood charcoal (witness)	7409.09	5.28	1.5
2	TA-90	3112.23	2.10	29.43
3	CA-90	5697.69	4.70	45.38
4	CTA-6030	5289.98	5.12	42.49
5	TP-70	4643.22	5.05	34.61
6	CP-70	5655.42	9.8	25.06

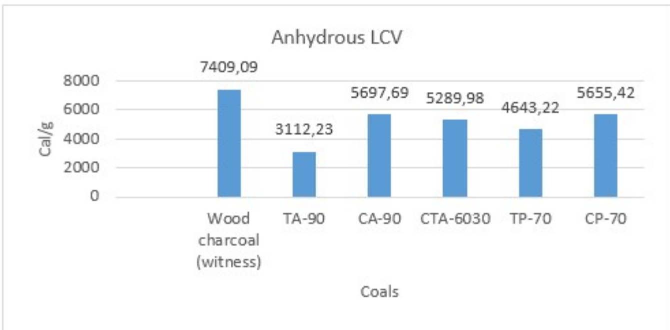


Figure 10. Comparative graph of LCV

It follows that the last two (2) samples CA-90 & CTA-6030 has the best ignition time. The same graph shows us that samples TA-90, CA-90 and CTA-6030 bring water to a boil faster than charcoal: respectively 11min41s for TA-90, 12min7s for CA-90 and 12 minutes

Table 7. Summary of the characteristic values of ecological coals based on Typha

Source	Literature values [20]			Results obtained		
Fuels	Charcoal	Ecological coal	Ecological coal	Charcoal	Ecological coal	Ecological coal
Composition	Charcoal	Typha 50% + rice husk 50%	Typha + clay (15%)	Charcoal	Typha 90% clay 10%	Typha 30% coconut shells 60% clay 10%
Humidity (%)	5.60	4.38	7.01	5.28	2.10	5.12
Ash content (%)	4.26	31.40	37.68	1.5	29.43	42.49
LCV (kJ/kg)	26,300	19,300	14,650	31,000	13,000	22,112
Ease of ignition(s)	61	42	11	300	328	180
Specific boiling time (min)	18	27	23	15	11	12

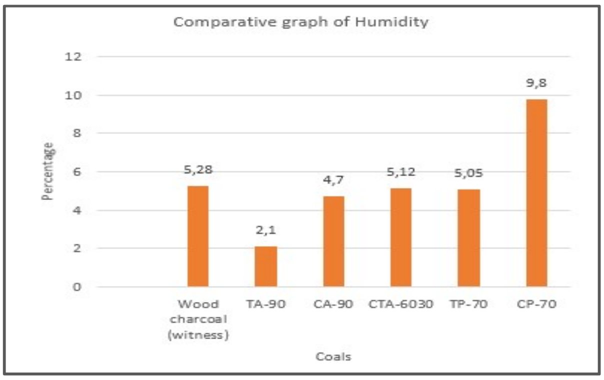


Figure 11. Comparative graph of humidity

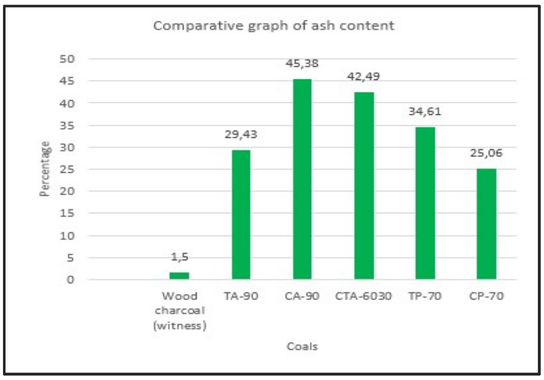


Figure 12. Comparative graph of the ash content

for the CTA-6030. Graph 8, meanwhile, shows us that it is the CA-90 sample that burns more slowly than all the others. While 170g of CA-90 was enough to bring a liter of water to a boil, it took 233g of charcoal to bring the same amount of water to a boil, and finally, CTA-6030 which requires 220g of biofuels to bring the same amount of water to a boil. These readings allow us to say that it takes more ecological coals TA-90 than wood coals to boil a liter of water while it takes less to achieve the same objective with regard to ecological coals CTA- 6030 and CA-90. In conclusion, CA-90 ecological coals have a better performance in terms of ignition time, boiling and quantity consumed compared to charcoal; next come the ecological coals CTA-6030. The objective being to manufacture ecological coals based on *Typha australis* and coconut shells, we have chosen CTA-6030 ecological coals which have a good performance compared to charcoal under the same conditions to carry out the controlled cooking tests. Below are the summary tables of the results of the Controlled Combustion Tests (Table 4 & Table 5). Figure 9 compares the amounts of fuel consumed to cook rice, beans and Bambara Groundnut. It shows that in the long term, ecological coals of the CTA-6030 type hold better in the hearth, therefore last longer than charcoal. While it takes 2.115kg of charcoal to cook 205g of Bambara Groundnut, 1.310kg of ecological coals of the CTA-6030 type are enough to cook the same quantity of Bambara Groundnut: which saves nearly 40% of fuel consumed. In this context, the characteristics of the ecological coals thus produced are as follows:

Graph 10 shows us that the CTA-6030 and CA-90 ecological coals have lower calorific values (LCV) of the order of 5,289.98 Cal/g and 5,697.69 respectively. These LCV are lower but close to that of charcoal. This is an acceptable performance, given the challenges mentioned above. Also, it should be noted that the moisture content of CTA-6030 and CA-90 which are respectively 5.12% and 4.70%: which are close to that of charcoal which rises to 5.28%. It turns out that Typha-based briquettes dry faster than charcoal. We find that all briquettes have an ash content that varies between 25 and 45%. This rate is very high compared to that of charcoal. This is due to the binder used in manufacturing.

In conclusion, CTA-6030 ecological coals are eligible to suitably replace charcoal: they are therefore ecological coals with high energy efficiency. Table 5 below presents a summary of some values obtained both in the literature and in the present study.

CONCLUSION

This study has enabled us to understand that tall invasive aquatic grasses are also to be valued as clean cooking energy. As far as *Typha Australis* is concerned, it will be necessary to strengthen the physico-chemical characteristics by combining it with other waste such as coconut shells, to make it efficient ecological coals that can replace charcoal. The development of Typha Australis will contribute to the clearing of waterways and thus facilitate navigation and by extension the development of tourism. It appears from this study that CTA-6030 is the best of the ecological coals with high energy efficiency studied in this study.

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