

Adoption of Clay Charcoal Briquetting to Curb Deforestation and the Impacts of Covid-19 Pandemic in Rural Areas, Kenya

J. Otieno and A. C. Otieno

ABSTRACT

Wood fuel is the principal source of energy in Kenya and contributes to more than 17% of the global deforestation. Saving on the amount of charcoal used at home will not only help save on cost that can be used to offset the economic burden caused by the impacts of COVID-19 pandemic but also control deforestation. This will foster the realization of more than 10% tree cover in Kenya by 2022 as per the presidential directive of 2019, Kenya Vision 2030 and the Constitution of Kenya 2010. This study aimed at promoting this goal by encouraging adoption of charcoal briquettes made from clay soil as a binder, charcoal dust and charcoal pellets as raw materials and ignited by pure charcoal (PC) to produce energy to form Clay Charcoal Blend Briquettes (CCBB). The study compared the amount of energy consumed by a household of five people using CCBB and PC. The results were: adoption of CCBB reduced the amount of charcoal used by 1.025kg per day, 21.325kg per week, 92.25kg per month and 1,122.375kg per year. This would save hundreds of trees from destruction. Additionally, using CCBB saved a household Ksh.45 (0.41USD) a day, Ksh. 945 (8.59 USD) a week, Ksh. 4,050 (36.82 USD) a month and Ksh. 49,275 (447.95 USD) a year as compared to using PC. The study therefore encouraged for adoption of CCBB concept.

Keywords: CCBB, COVID-19 pandemic, deforestation, PC.

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I. INTRODUCTION

More than 2.4 billion people globally depend on charcoal and wood fuel as their main sources of energy in towns and in rural areas [7], [11]. About 25% of the world forests is cleared globally [6]. Approximately 17% of wood used worldwide is converted into charcoal, whose production is expected to continue rising in the coming decades [7]. In Sub Sahara Africa (SSA), wood-based fuels account for over 80% of primary energy supply and more than 90% of the population rely on charcoal and fire wood [8]. Charcoal is the principal fuel in Kenya [10] providing energy for 82% for urban and 34% for rural households [12]. The high demand for wood fuel has contributed to deforestation and its subsequent environmental challenges like soil erosion, global warming and climate change [7]. Hence the need for an alternative source of energy to complement or supplement wood fuel to conserve the dwindling forest reserves in Kenya which currently stands at less than 10% [19].

Wood extraction for charcoal and firewood is one of the most dominant drivers of forest cover loss in Kenya [13] particularly in the Arid and Semi-Arid woodlands. In Coastal Kenya, the high demand for wood energy in Mombasa city has caused deforestation in Kwale County which is the key source of wood fuel for the city. In Nyanza, Western as well as other regions of Kenya, the high demand for wood energy for domestic use and also for fish smoking especially around Lake Victoria has caused degradation of forests in the region [13].

Efforts have been made to restore the country's forest cover back to 10% as enshrined in the country's long term vision 2030 and the Kenyan's constitution 2010 [4]. To achieve this goal, the government of Kenya through a Presidential Directive (PD) of 2019 has called for the realization of the constitutional requirement of at least 10% trees cover by 2022 [16]. Among the PD strategies are reforestation programs as well as encouraging the use of alternative sources of energy such as use of kerosene, Liquefied Petroleum Gas (LPG) by lowering of taxes on them among others.

Nevertheless, the cost of kerosene and LPG are still high, beyond reach by many consumers especially in rural areas. The introduction of fuel anti-adulteration tax on kerosene by Energy and Petroleum Regulatory Authority (EPRA) in 2018 led to rise in prices of Kerosene which was the cheapest and most preferred non wood source of energy by the low class. Consequently, many people shied away from using kerosene leaving an energy gap among the poor class which has been filled by embracing more charcoal usage.

In response to the scourging effects of COVID19 pandemic, which has destabilized the global economy, [18], there is need for cheap, affordable, and eco-friendly source of energy to supplement wood fuel which is the dominant source of energy especially in rural areas [3]. To achieve this goal and also help minimize deforestation as well as help clean the environment, the study adopted the use of clay soil as a binder, since it is naturally available, charcoal dust and

charcoal pellets as raw materials for making charcoal briquette. The briquette made was blended with pure charcoal (PC) in small quantities to provide heat energy hence forming Clay Charcoal Briquettes Blend (CCBB). The use of charcoal dust and charcoal pellets which are residues of charcoal is a way of recycling which help reduce energy consumption and clean the environment [20]. Thus, this study will help reduce emission of Green House Gases (GHG), mitigate climate change and global warming and also increase access to energy, food and provide income generation activities [7], [9], [17].

Various studies have used different technologies and materials to make charcoal briquettes for instance [1] used sesame stalk, [15] used bagasse, [14] used charcoal dust without charcoal pellets among others. In these studies, mechanical power was used to compact briquettes. However, their techniques were rather complicated as compared to CCBB and cannot be used by ordinary individual households who may not be able to afford the cost of the required machinery or tools. Such studies have involved the use of Kiln for heating, mechanical source of pressure such as piston extruders, screw extruders and rollers which are not readily available in the rural areas. Thus, the use of CCBB is a different approach which does not require any form of mechanization and artificial heating application but hand compaction and direct solar heating. Adoption of the CCBB concept will help the Government of Kenya (GoK) realize its vision of achieving 10% forest cover by 2022 and by the year 2030 as per the Kenya's long term Vision 2030.

II. RESEARCH METHODOLOGY

A. Materials and Methods

This research was taken in the rural part of Homa Bay County, Kenya. It adopted experimental research design and random sampling technique of 50 respondents living in Kochia West Sub-location, Homa Bay County. Both primary and secondary data collection techniques were used. The primary data were on: friability, heating capacity and length of burn of the briquettes, energy saved and cost benefit of using CCBB, rural respondents' awareness on the use of CCBB in energy production and environmental conservation and willingness to embrace briquettes in their daily cooking ventures. The secondary data were from published data available online.

B. Making of Briquettes

This research used a mixture of charcoal dust and charcoal pellet as raw materials to make briquettes. Thus, it did not require carbonation process as it involves recycling of charcoal wastes which are already carbonized. The research encompassed the following processes:

Binding process: The research used clay as a binder since it is readily and freely available in most parts of rural areas in Kenya. Other studies have used other binding materials such as cassava flour, molasses, wheat flour among others [15], [1]. However, these gluing materials are expensive to acquire and not readily available among the rural energy poor households. The charcoal wastes (charcoal dust and pellets) were mixed with fine clay soil in the ratio of approximately 5:2 using water to form 'dough'. The ratio of approximately

5:2 was maintained in order to produce high quality briquettes which burn effectively with high heating capacity. Unlike other studies that used high pressure and temperature for binding [15], [1], this approach does not require such.

Compaction process: Hand compaction method was used to manually compress the 'dough' into fist sizes. It was thoroughly done to squeeze out water from the dough and form a well compacted agglomerate.

Heating process: Wet briquettes are aired in the sun to dry. They are laid in lines on polythene sheet, concrete slab (Plate 1) or dry open ground and turned 2-3 times a day depending on the intensity of the insolation for even drying. The briquettes were lined about 5cm apart to reduce shading effects from interfering with the drying process. Direct solar heating was used due to availability of abundant solar energy in Kenya. It takes 2-3 days depending on the availability and intensity of the solar insolation. The use of the free solar energy in the drying process makes the production of charcoal briquettes cheaper and more affordable as compared to use of kiln [15], [14].



Plate 1. Clay charcoal briquettes drying on a water tank concrete slab.

Packaging and storage: Dried briquettes are packed into sacks and stored just as ordinary charcoal. However, caution should be taken to avoid wet conditions since clay bonded briquettes disintegrate when they come into contact with water unlike ordinary charcoal which can be re-dried. Another precaution to take is avoiding piling of heavy materials on the briquettes since this will break them.

Ignition and usage: Dry clay charcoal briquettes are used together with ordinary charcoal pure (PC) in *Jikos* (charcoal stoves). First, the *jiko* is filled between quarter to half way with PC and ignited the usual way. The charcoal is allowed to ignite first and then the *jiko* is filled with briquettes.

C. Briquettes Performance Test

Briquettes quality test: The quality of the briquettes (CCBB) produced were tested using two tests namely: weight test and friability test. Weight test involved determining the weight of single dry and ready to use pieces of CCBB using electronic balance. Friability test was carried out by dropping the briquettes by hand from a height two meters above concrete ground five times to determine their resistance to crushing [1].

Briquette Heating Capacity test based on Pressure Release Frequency (PRF) Technique:

This was tested using pressure release from a 3L capacity pressure cooker (Plate 1). This technique was suitable for the

study since it is heat that initiates the pressure released by the pressure cooker. The PRF of the pressure cooker was determined by comparing the number of pressure released from a *jiko* filled with PC and the same *jiko* when filled with CCBB. The time taken between the first and the last pressure releases and their intervals were taken using a stop watch. The study assumed that: the higher the PRF of the heating material, the higher its heating capacity.



Plate 2. Using pressure release frequency (PRF) technique from a 3L capacity pressure cooker to determine the heating capacity of CCBB.

Length of burn: This is the duration the briquette takes to completely burn before going off or stops producing pressure in comparison to pure ordinary charcoal. To be succinct, this duration was determined from the time the first pressure was released and the time the last pressure was released.

III. RESULT AND DISCUSSION

A. Briquette Quality Tests

Weight test: The result of this test showed that CCBB with an average weight of between 30g-50g were easier to ignite and burn easily as compared to those with weights above 50g. However, this might depend on the size of thumb that produced the first size briquettes. Thus, the higher the weight of the CCBB, the higher the clay soil content and the lower the quality of the briquette and difficulty in ignition and combustion.

Friability test: The CCBB crushed and reduced in size drop wise with the final drop producing fragments. Friability test done on briquettes made of sesame and clay in Ethiopia showed more than three quarters (85.2%) resistant to crushing [1]. Drop test of the same height on saw dust and coffee husk in Kenya with 15% clay as a binder was found to be 48% and 44% respectively [2]. The low friability of CCBB does not disqualify it for use but discourages its transportation over long distances or piling pressure on it.

B. Comparison of the Heating Capacity of CCBB and PC

1. Pressure Release Frequency (PRF) technique

The result (Plate 2), had it that the frequency of pressure released from CCBB was more than double (27) while that from PC was 12 (Fig. 1). [14] found out that briquettes made up of charcoal dust supply an additional energy of 16% of the cooking fuel.



a) Air hole fully open



b) Air hole partially open



c) Air hole partially opened and sufuria removed
Plate 3a, b and c. Flame qualities of clay charcoal briquette.

2. Flame strength test

From Plates 3 “(a),” “(b),” and “(c),” the orange color of the flame was an indicator of high quality and strength. The flame intensity increased with increase in air space (opening of the air hole) as shown in Plate 3 “a”. However, when the air hole was fully opened Plate 3 “b”, the briquettes burnt faster with long flames but for a shorter time as compared to when the air whole is partially opened. The briquettes burn without smoke hence less harm full to human health.

3. Comparison of the length of burn between CCBB and PC

The interval between the first pressure and the last pressure releases were 32 minutes and 3 seconds for CCBB with PRF of 27 and 19minutes 42seconds for PC with PRF of 12 (Fig. 1). However, it was noticed that CCBB takes a longer time to produce the first pressure than PC. This was because it takes time for the briquettes to be ignited and release heat energy to induce pressure.

From Fig. 1, it is clear that CCBB releases heat energy for a longer duration as compared to PC. CCBB also releases pressure at shorter intervals as compared to PC implying stronger heat energy capacity of CCBB. However, the length of interval frequencies towards the last pressure release increases in each case with CCBB having longer intervals. This shows higher heat energy retention capacity of CCBB over PC.

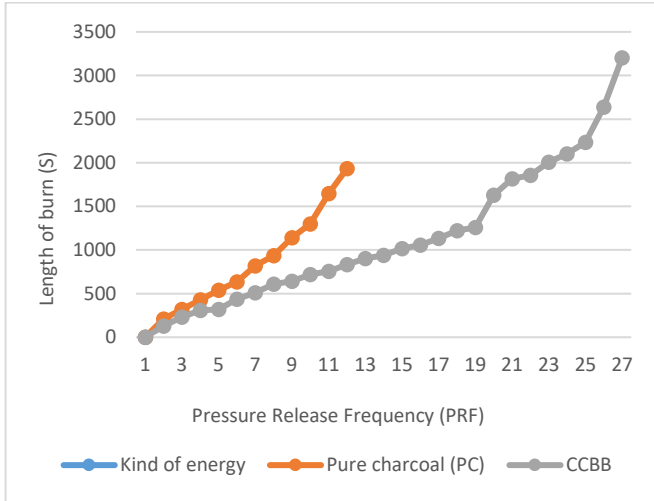


Fig. 1. Length of burn (s) between PC and CCBB based on frequency of pressure released (PRF).

C. Cost benefits of using CCBB over PC

In the area of study, charcoal is mostly retailed in small polythene packets. It was reported that 1 polythene packet of charcoal was used to prepare one meal in a household size of five people, thus in a day, 3 packets were used to prepare 3 meals of breakfast, lunch and supper. One packet of charcoal costed Ksh. 30 (0.27 USD) hence 3 packet of charcoal costed Ksh. 90 (0.819 USD) in a day. 1 polythene packet of charcoal weighed approximately 0.55 kg while the same packet filled with clay charcoal briquette weighed about 0.8 kg Thus in a day, 1.85 kg of charcoal was consumed by one household.

When using CCBB, 1 packet of charcoal (PC) (0.55 kg) was required to prepare 2 meals in a day consuming a quarter packet of the briquettes (0.2 kg). Thus, 4 packets (2.2 kg) of PC required 1 packet (0.8 kg) of briquette to burn. Therefore, 0.825 kg of charcoal costing Ksh.45 (0.41 USD) was consumed in a day using the CCBB. In a week, there are 21 basic meals, 90 in a month and 1095 meals in a year as summarized in Table 1.

TABLE I: SUMMARY OF AMOUNT OF FUEL ENERGY (KG) USED AND COST (KSH./ USD) OF USING PC AND CCBB

Energy used	A day (3)	A week (21)	A month (90)	A year (1,095)
Pure charcoal (PC)				
Energy required (kg)	1.85	38.85	166.5	2,025.75
Cost of energy (Ksh./USD)	90 (0.82)	1,890 (17.18)	8,100 (73.63)	98,550 (895.90)
CCBB				
Energy required (kg)	0.825	17.325	74.25	9,03.375
Cost of energy (Ksh./USD)	45 (0.41)	945 (8.59)	4,050 (36.82)	9,275 (447.95)
Cost of energy saved= Cost (PC-CCBB)	45 (0.41)	945 (8.59)	4,050 (36.82)	49,275 (447.95)
Amount energy saved=Energy (PC-CCBB)	1.025	21.325	92.25	1,122.375

Assumptions of the study were:

- i) That all the households only used charcoal as the source of fuel energy for cooking.

- ii) That three meals are prepared in a day.
- iii) CCBB are not purchased and are prepared by individual household members.
- iv) That charcoal dust and pellets are obtained freely from usual household purchase of charcoal or from charcoal dealers.

From the result in Table 1, it is explicitly clear that adoption of CCBB saves the cost of fuel energy by half and amount of energy (kg) by more than half. Thus, adoption of CCBB concept, will help save more than half of the trees that are to be cut down for charcoal production. This will help increase forest cover in Kenya and assist the Jubilee government to achieve its vision of 10% forest cover by 2022. Additionally, the cost saved by embracing CCBB (Table 1) would help offset the economic burden caused by the effects of COVID 19 pandemic.

D. Awareness of the Use of CCBB as a Source of Fuel Energy in Rural Areas of Homa Bay County

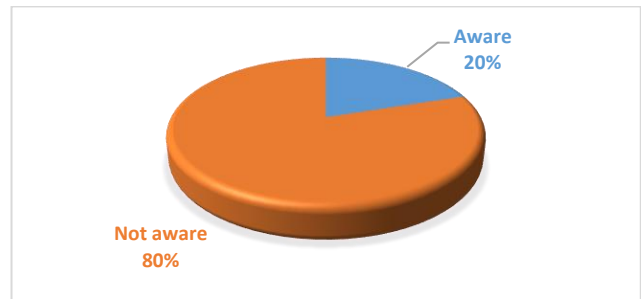


Fig. 2. Awareness on the use of CCBB as a source of fuel energy in rural areas.

From Fig. 2, it is explicit that more than three quarters of the respondents (80%) were not aware of the use of CCBB. This leaves fire wood and PC as the main sources of energy causing deforestation and its consequent environmental challenges such as: soil erosion [5], global warming and climate change [20], [7]. Only 20% of the respondents (Fig. 2) were aware on the use of CCBB as fuel. They reported that they learnt of the briquette concepts while staying in slums of Kibera and Kawangware in Nairobi, Kenya. However, they have not practiced the concept in their rural areas. This revelation points to knowledge gap of CCBB usage in rural areas. Thus, the need for creation of awareness on the importance of briquettes in supplementing PC in order to save energy, its cost and conserve trees hence controlling deforestation and its effects. The cost of fuel saved would help mitigate the economic effects of COVID-19 pandemic.

E. Clay Charcoal Briquetting and Associated Environmental Problems

The use of clay as a binder in charcoal briquetting is the cheapest way of making briquettes in areas with clay soil. However, the extraction of clay soil from the earth causes other environmental challenges that need to be checked. The study empirically found out that CCBB was associated with creation of open ditches in compounds of home steads which make the land surface rugged and a threat to animals and children especially at night. The open ditches when filled with water (Plate 4) act as breeding grounds for mosquitoes which cause malaria posing serious health problems. The

open ditches also make the environment ugly and distort its natural aesthetic value which is a key pillar in tourism attraction and natural therapy. The bareness of the soil (Plate 4) caused by ditching effects accelerate soil erosion.



Plate 4: Ditches created as a result of extraction of clay soil for charcoal briquetting causing environmental challenges.

IV. CONCLUSION

In conclusion, the adoption of CCBB, will save the amount of charcoal used per household size of five by 1.025 kg per day, 21.325 kg per week, 92.25 kg per month and 1,122.375 kg per year. This would prevent hundreds of trees from destruction. Additionally, embracing of CCBB would save a household Ksh.45 (0.41USD) a day, Ksh. 945 (8.59 USD) a week, Ksh. 4,050 (36.82 USD) a month and Ksh. 49,275 (447.95 USD) a year. This cost will help offset the economic burden imposed by the effects of the COVID-19 pandemic. PRF test showed a stronger heating capacity of more than double (27) of CCBB as compared to 12 of PC. The length of burn of CCBB was longer than PC at 32 minutes, 3 seconds and 19 minutes, 42 seconds respectively. Weight test of the CCBB showed that briquettes weighing between 30 g-50 g were easier to ignite and burnt easily as compared to those with weights above 50 g. Friability test of the CCBB showed a weak a bound as the briquettes disintegrated dropwise to fragments. It was found that 80% of the respondents were not aware of the CCBB concept. The environmental problems associated with CCBB was creation of open ditches on the ground which acted as breeding grounds for mosquitoes causing malaria, destroy the aesthetic value of the environment and pose danger to moving animals and children.

RECOMMENDATIONS

The study strongly recommends for adoption of CCBB in order to save on the cost of fuel, conserve trees and clean the environment. Creation of awareness on the importance of CCBB in controlling deforestation and environmental sanitation. Treating of the stagnant waters with oil to control breeding of mosquitoes. Limiting the number of sites for extraction of clay and filling in un used ditches with ash from CCBB and other organic materials to accelerate pasture regrowth.

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