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Original Article

Unpacking the Concept "Green Charcoal," A Cooking Fuel Innovation: The Gulu University Interdisciplinary Experience

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ABSTRACT

Introduction: This paper reviews the concept of "Green Charcoal," drawing extensively on lessons learned from the UPCHAIN project implemented at Gulu University. **Methodology:** Based on research conducted by Work Package Two of the UPCHAIN project, complemented by a comprehensive literature review, this study examines the definitional ambiguities, practical challenges, and socio-environmental considerations inherent in developing sustainable charcoal alternatives within the unique context of Northern Uganda. **Key results:** The study defines Green charcoal as a clean, eco-friendly solid biofuel produced through the carbonisation or densification of biodegradable, carbon-rich organic waste materials such as agricultural residues, forestry by-products, and household waste using efficient, often mechanised, briquetting technologies. Historically, firewood and traditional charcoal have been the primary cooking fuels in the region, valued for their affordability and accessibility. Green charcoal is now emerging as a promising, sustainable alternative, marking a potential shift in the energy landscape. Households across both rural and urban settings commonly employ a combination of cooking fuels. There are vast definitions for green charcoal, coupled with acceptances and rejections. **Conclusion:** Most households in the region still depend on firewood and traditional charcoal because they are affordable and easy to get. Challenges in access and distribution, coupled with fierce competition from the informal traditional charcoal sector, complicate the widespread acceptance of green charcoal. Green charcoal has been embraced because of its environmental benefits (less deforestation), health advantages (less smoke), economic potential, and the availability of local raw materials. However, it's often rejected due to higher initial costs, being harder to light, producing more ash, not fitting traditional cooking methods, and inconsistent quality. **Recommendations:** Addressing affordability and accessibility gaps, integrate green charcoal with existing cultural norms and practices, integrating green charcoal with existing cultural norms and practices, and enhancing perceived value and usability.

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INTRODUCTION

In 2022, Gulu University was awarded Danish International Development Agency (DANIDA) research towards the multi-disciplinary innovation of the Green Charcoal in Northern Uganda under the UPCHAIN (Unlocking the Potential of Green Charcoal Innovations to Mitigate Climate Change in Northern Uganda) project. The Project is expected to run from 1st May 2022 to 30 April 2026. The Project is financed by the Danish Ministry of Foreign Affairs. The project's focus was on how to develop an inclusive innovation model on green charcoal adoption, a wood fuel solution that would provide change in social practices and thereby support climate change mitigation and reduce deforestation in relation to fuel use in cooking in the sub-Saharan region. However, Kung et al. (2015) observed that green charcoal production often encounters mixed reactions. On the one hand, it is often lauded for its potential to manage waste, improve the environment, and most importantly, create new jobs (Kung et al., 2015:98).

The objective of this paper was to review the concept of Green Charcoal using the lessons learned from the UPCHAIN project at Gulu University. The paper was based on research undertaken by Work Package Two and literature review, and it sought to provide a broader perspective of the concerns surrounding green charcoal conceptualisation and production in the context of Northern Uganda. This paper contributes to the knowledge on Green Charcoal, especially those that aim at broadening research and innovation aimed at attaining environmental sustainability.

Understanding the charcoal situation has always been hampered by lack of reliable information, partly because only a very small fraction of charcoal production is recorded and assessment of the actual magnitude of use, and the impacts on forests and rural livelihoods, has consequently been difficult to determine although this has been the subject of considerable debate (Chidumayo et al., 2013: 87). The immediate impact of charcoal in northern Uganda has been seen in the depletion of natural vegetation covers.

From the inception of the project, the buzzword was "Green Charcoal". This raised the critical questions: How do we define Green Charcoal? Is Green Charcoal defined by its purpose of production? Or is it defined by the production process or the nature of raw materials used in its production? The paper further questions whether Green Charcoal is defined by the outcome and the related change in the individuals and community. The UPCHAIN Project was to show that the 'green' is a premium and people-based solution.

This paper was motivated by the Intellectual Property Rights Clause (7.3) of the Project documents.

Software, patent applications, patents, knowledge, know-how, data, research results, as well as other information and intellectual property rights

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generated directly by a Party in connection with work outside the Project, or otherwise controlled indirectly by a Party via a license and which such Party permits to form part of this Project ("Background Knowledge") shall remain the sole property of the Party, who brings such Background Knowledge into the Project.

The right of ownership to software, patent applications, patents, knowledge, know-how, data, research results, as well as other information in general and intellectual property rights generated by one or more Parties in connection with the execution of the Project ("Foreground Knowledge") shall accrue to the Party, whose employees have generated the relevant Foreground Knowledge. Such a Party may freely control its own Foreground Knowledge and may commercially use and take out patents for such Foreground Knowledge.

In the event that employees of one or more Parties have jointly generated the Foreground Knowledge, the rights in such Foreground Knowledge accrue to the Parties for joint ownership by way of ideal shares in proportion to the respective intellectual contributions by the employees. In addition, jointly owned Foreground Knowledge is governed by the following provisions: (i). Any control over the jointly owned Foreground Knowledge, including any commercial use, assignment of a Party's ideal share or patenting, is subject to agreement between the Parties. In the event that any Party wishes to take out a patent on the basis of jointly owned Foreground Knowledge, the Parties must enter into a separate agreement to form the basis of such situation. (ii). Each Party is, however, entitled, free of charge, to make use of the jointly owned Foreground Knowledge for research and educational purposes within any scientific area (**UPCHAIN-Project Partnership Agreement, 2022).**

This Intellectual Property Rights Clause provides for contextualising the innovation, which takes the form of the technology, knowledge, technical know-how, and practices generated during the project implementation. Documenting the Gulu University perception of Green Charcoal contributes towards generating knowledge within its Community of Practice.

RESEARCH METHODOLOGY

The UPCHAIN Green Charcoal project was an offshoot of the Gulu University Building Stronger Universities Project phase III, which, among others, aimed at addressing the problem of the depleting vegetation in Northern Uganda. The qualitative approach with a historical design was used to trace the state of cooking practices and fuels used in Northern Uganda, as well as the conceptualisation of Green charcoal. The study used a sample size of 81 participants, determined at a saturation point, across the three districts of Adjumani, Amuru and Gulu, in Northern Uganda. The study reviewed existing literature to collect secondary data, baseline surveys (involving Focus Group Discussions and participant observation) and ranking to collect the primary data.

Review of Literature:

In exploring the phenomenon under study, systematic, scoping, and integrative reviews of literature each served as valuable methods of secondary data collection. The **systematic review** allowed the researchers to gather and critically appraise empirical studies that evaluate the conceptualisation of green charcoal technologies, offering a structured comparison of environmental, health, and economic impacts in similar contexts to that of Gulu University. In contrast, the **scoping review** took a broader approach, mapping a wide range of literature, including academic articles, policy documents, and grey literature, to explore the development, implementation, and reception of green charcoal and related sustainable fuel innovations across different regions. This helped situate Gulu University's initiative within a wider landscape of institutional and community-based efforts. Meanwhile, an **integrative review** provided the most holistic perspective by synthesising both empirical data and theoretical insights from diverse disciplines. It helped in understanding the technical and environmental aspects of the innovation, as well as its socio-cultural

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implications, policy relevance, and contribution to academic research and community engagement. Together, these review methods offered a comprehensive toolkit for collecting and analysing data on the multifaceted impact of green charcoal as a sustainable cooking fuel innovation.

Baseline Surveys:

Baseline surveys were indispensable for unpacking the users' perception of the Green charcoal cooking fuel as they provided a critical "before" snapshot of the target communities, collecting essential data on current cooking fuel consumption, socio-economic conditions, environmental practices, health indicators, and existing awareness. This initial data served as a vital reference point, enabling the study to accurately measure and attribute any subsequent changes or impacts (such as reduced traditional fuel use, cost savings, or improved health) directly to Gulu University's green charcoal initiative. This helped in quantifying its efficacy to serve as a benchmark for monitoring and evaluation that will inform future program design and targeting efforts. These surveys were conducted with the use of data collection methods like focus group discussions and participant observation.

Focus Group Discussion (FGD)

The study used nine FGDs (three from each district) to facilitate discussions with small, homogenous groups of 6-10 individuals, aiming to gather collective views, explore group dynamics, identify shared challenges, and generate diverse opinions regarding Green charcoal. The discussions were guided using a prepared FGD guide with open-ended questions and prompts. Three independent groups, with women (primary cooks), men, and youth, were involved in each district and crucial to understanding shared experiences related to fuel collection, cooking practices, energy needs, perceptions of green charcoal, and its social acceptance and or rejection.

Participant Observation

This involved the use of an observation checklist to record observable behaviours, conditions, or characteristics in a standardised manner, thereby minimising subjective bias. Hence, this was employed to objectively document the types of cook stoves used in households, the presence and quantity of traditional fuel stockpiles, the characteristics of cooking environments (such as ventilation and smoke levels), and the food cooked with the preferred cooking fuels.

Ranking:

Ranking was used to ask participants to prioritise or order items (ideas, needs, problems, solutions, preferences, etc.), focusing on the *why* behind participants' choices and the meanings they assign to their rankings. The use of a ranking matrix allowed participants to assess green charcoal in relation to other fuel options (e.g., firewood, traditional charcoal, LPG, briquettes) by scoring or ranking them based on selected attributes, such as cost, availability, health impact, environmental friendliness, and ease of use were the key.

The collected data underwent thorough analysis. This involved transcribing the information and engaging in in-depth discussions to openly and descriptively code it. This interpretive coding process helped to identify recurring themes and segments within the data, regarding the state of cooking and coking fuels used in Northern Uganda, and the conceptualisation of green charcoal based on its acceptances and rejections. The study interpreted these identified themes specifically within the Northern Uganda context, carefully considering any nuances, contradictions, or surprising discoveries. Researchers also actively checked for biases and incorporated diverse perspectives. To enhance the article's credibility and reliability, participant quotes were included to support the study's aims. Lastly, this research project was approved by the Gulu University Research Ethics Committee (GUREC), under reference number 2023-641. The study followed the ethical guidelines outlined in the Declaration of Helsinki. Before

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participating, all individuals gave their informed verbal consent, and only those who consented were included in the study.

RESULTS AND DISCUSSION

The State of Cooking and Cooking Fuels Used in Northern Ugandan Households

In a baseline survey conducted in 2022 to establish the state of cooking practices and fuels used across Northern Uganda districts, the study identified the following commonly used source of cooking fuels: Black charcoal (*maka*), Firewood (*yen*), Agricultural residues (*cung* - depending on the specific plant), green charcoal (*bilo maka*), Biogas, Kerosene Oil (*moo tara*), Gas (*me tedo*), and Electricity (*mac tedo*).

Ranking of Fuel Options (1 = Worst, 5 = Best)

Fuel Option	Cost	Availability	Health Impact	Environmental Friendliness	Ease of Use	Average Rank
Green Charcoal	4	3	5	5	4	4.2
Firewood	5	5	1	1	4	3.2
Black Charcoal	3	4	2	2	4	3.0
LPG	1	2	4	3	3	2.6
Electricity	1	3	2	4	1	2.2
Agricultural residues	5	4	2	2	3	3.2

From the above matrix, **Green Charcoal:** Assumed to be relatively cost-effective (4), improving in availability (3), highly beneficial for health (5) and environment (5), and reasonably easy to use (4). **Firewood:** Often the cheapest and most available (5,5), but with significant negative health (1), environmental (1) impacts, and ease of use (4). **Black Charcoal:** More expensive (3) than firewood but less than LPG and electricity, widely available (4), but with negative health (2) and environmental (2) consequences. Relatively easy to use (4). **LPG (Liquefied Petroleum Gas):** Often the most expensive initially (1) and less universally available than solid fuels (2), but good for health (4) and somewhat environmentally friendly (3), with a very high ease of use (5). **Agricultural residues:** Can be very cheap (5) and relatively available (4). Yet, their health (3) and environmental (2) impacts are generally better than firewood but not as good as green charcoal or LPG, and the ease of use is moderate (3).

However, for decades, firewood and black charcoal have been the primary cooking fuels in rural areas, driven by their availability and affordability, a trend that reflects wider socioeconomic and environmental changes. While urban areas have supplemented these with gas, rural households have historically relied almost exclusively on firewood and charcoal. In an interview with an elder in Kulukeno village in Owoo Sub-county, Gulu District, she affirmed that:

> *People at this time began active and large-scale agriculture, and so, they cleared the trees that easily provided firewood. Other families survived on the charcoal trade to generate income, since there was a ready market for charcoal in town. The emergence of the LRA insurgency also scared people from going to forests and bushes to collect firewood for fear of abductions and killings, so they became so reliant on black charcoal.*

Over the past decade, a notable shift has emerged with the introduction of green charcoal due to the increasing environmental concerns, indicating a move toward more sustainable energy solutions. Currently, rural households use a mix of firewood, charcoal, and green charcoal, while urban residents combine charcoal, green charcoal, gas, and electricity for their cooking needs. Findings from the participants' rankings established that the preference for a combination of fuels in both

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rural and urban settings is largely influenced by factors like affordability, accessibility, and cultural norms. Interestingly, despite ongoing rural electrification efforts in rural areas of Northern Uganda, electricity has not been widely adopted for cooking. This finding aligns with related studies in Gulu District by Okello et al. (2024), who similarly mentioned that most households often cite high costs and perceived health risks (such as electric shocks) as reasons for this resistance, a unique finding emphasised by this study.

The introduction of green charcoal as a sustainable alternative signals a shift in energy policy and environmental awareness. This finding is in agreement with related studies by Maes and Verbist (2012), who similarly re-echoed that eco-friendly cooking fuels like green charcoal reduce carbon emissions and, on the environment, and offer a sustainable solution for cooking fuel needs. Although the adoption rates are still low, people have borrowed the knowledge and begun moulding such briquettes locally using clay and charcoal residues. However, the study observed that the continued use of charcoal still remains high, especially among the urban households, while firewood remains dominantly used in the rural households since it is easily accessible and at in most cases, at no cost.

Throughout the observation phases of the study, households use a wide range of cook stoves, depending on the cooking fuel. Three-stone fireplace (compatible with firewood), Ordinary charcoal stoves (compatible with green and black charcoal), Energy-saving charcoal stoves (compatible with green and black charcoal), Energy-saving firewood stoves, Gas stoves, Kerosene Oil stove, Biogas stove, Electricity cookers/ plates.

Process of Defining Green Charcoal

As the project kicked started, the project team had not come up with a concise definition of Green Charcoal. However, a working definition of Green Charcoal was agreed upon as: A cooking fuel produced out of agricultural raw materials or residues, including rice husks, groundnut husks, cotton stalks, and any other agricultural residues.

The project's Work Package One was tasked to develop a locally contextualised green charcoal production model and roadmap that could be adopted by households, the private sector, and other public institutions in Uganda, including researching the technical aspects and greenhouse gas emissions.

Conceptualising Green Charcoal:

Existing studies indicate that the application of biomass to generate energy has been highly studied as an alternative to fossil fuels (Zanella et al., 2017:199)

Green charcoal has been given different names, including: Green coal (Malak et al., 2016); Green Charcoal Briquettes (Zanella et al., 2017), Green Energy and briquette (Yustas et al., 2022), Biomass briquette (Wu et al., 2025:44), agricultural waste briquette (Yuan et al., 2021), charcoal briquette (Mwampamba et al., 2013; Pawaree et al., 2024), agricultural and organic residue briquette (Okello et al., 2024), among others.

Definition of Green Charcoal: What It Is and What It Is Not:

The term green charcoal has had contestations. There have been acceptances and rejections based on the user and community perceptions.

UNDP Definition

The UNDP (2013) in a study: "Nationally Appropriate Mitigation Action Study on Sustainable Charcoal in Uganda," identifying major opportunities in the charcoal sector to prevent carbon emissions and foster sustainable development in least developed countries, defines green charcoal denotes as improved and sustainable charcoal. Sustainable charcoal involves both sustainable forest management and the use of efficient kilns. Similarly, improved charcoal is charcoal produced using efficient kilns where the efficiency of charcoal production is higher than that of traditional kilns. The

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traditional kilns are the pit kiln and the surface earth-mound kiln. Therefore, the term "green" charcoal is used to collectively represent sustainable and improved charcoal (UNDP, 2013:38).

The Government of Uganda's Definition

Whereas the long-term development of the charcoal value chain does not form a critical part of Uganda's long-term energy strategy, the Government of Uganda realizes the importance of charcoal in the country's energy planning and the need for a comprehensive strategy to promote sustainable charcoal production. The Ministry of Energy and Mineral Development, in response, initiated the development of a BEST (Biomass Energy Strategy) and the proposed National Task Force for biomass energy. However, given the socio-economic importance of charcoal production, the shift from conventional charcoal production to sustainable production needs to be gradually introduced to avoid disturbing the existing social fabric (UNDP, 2013:25, 39; Labeja, 2019).

'Green Alternative', Bio-char, or Ecological Charcoal

Business in Cameroon (2023) network reporting about UNDP empowering Maroua women with an eco-friendly charcoal production unit, described the green charcoal as solid fuel made from biodegradable, carbon-rich residues (agricultural or household), compacted into briquettes or balls, serving as a green alternative. "Also known as green charcoal or bio-charcoal, ecological charcoal is a solid fuel produced from biodegradable agricultural and household residues rich in carbon. It is one of the innovative local solutions currently being developed in several developing countries of Africa, including Uganda. Depending on the geographical area and economic activities, it can be produced from various organic waste (sawmill residues, agricultural waste, household waste, agri-food industry waste). It comes in the form of briquettes or balls, similar in size to traditional charcoal pieces," explains the UNDP (Business in Cameroon Network, 2023).

Salma et al. (2024) referred to green charcoal as 'Biochar', a form of charcoal, which is the product of the conversion of organic materials, such as agricultural waste and forestry by-products, into a stable form of carbon that can be stored in soils for centuries. They argue that Biochar offers a unique and sustainable approach to the carbon offset mechanism with the potential to revolutionise carbon sequestration and agriculture. The Intergovernmental Panel on Climate Change (IPCC) identified biochar as one of the carbon dioxide removal (CDR) methods to be applied in agriculture for storing carbon in the soil (Salma et al., 2024:2). Biochar has gained recognition as one of the potential carbon offset solutions. They further consider biochar as an adaptable and scalable technology with the potential to contribute significantly to carbon credits, aligning with the Sustainable Development Goals. However, it calls for continued research, transparency, and international cooperation to explore the full potential of biochar in climate change mitigation efforts (Salma et al., 2024:1).

Definition by Process

Green charcoal has also been defined based on the process. Yustas et al. (2022) refer to them as briquettes. Kumar et al. (2021) defined green charcoal by the production process called briquetting, in which biomass is compressed into briquettes.

Mwampamba et al. (2013) define Charcoal briquettes by the material and process involved in producing them. They noted Green Charcoal as a process through which solid fuel is made from carbonised biomass, or densified biomass that is subsequently carbonised.

Definition by Production Material

Green charcoal has been defined from the background of the nature of the raw materials used in its production. Mwampamba et al. (2013) define Green Charcoal as cooking fuel produced

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from biomass residues, including by-products of the commercial forestry, agricultural, and industrial sectors. These residues are often considered ‘waste products’ and include rice, coconut and coffee husks, nut shells, wood shavings, charcoal fines, and sawdust. They are often considered ‘waste products’.

Definition by Motive of Greening the Environment

The rationale for producing briquettes was primarily economic, and to salvage unused waste and convert it to marketable fuel that can be transported over long distances. The first known patents for briquetting technology were recorded in the mid-1800s in the USA, when high prices of coal required more efficient use of the waste products from mining. During World War II, following the fuel shortages, briquetting of other waste materials such as sawdust became widespread in Europe, America, and Japan. In Asia and Africa, briquetting has been motivated by a desire to mitigate energy loss, air pollution, and greenhouse gas emissions associated with inefficient burning or disposal of biomass residues. In Sub-Saharan Africa, where evidence exists that forests have been degraded and cleared for charcoal, green charcoal briquettes were viewed as a solution to the unsustainability of traditional, forest-based wood charcoal production systems, which have caused environmental degradation, triggering climate change. This calls for alternative fuels to restore a green environment (Mwampamba et al. 2013: 159).

Definition by Technology and Means of Production

Green charcoal has also been defined by the briquetting technology (Mwampamba et al., 2013). Okello et al (2024) defined Green Charcoal as the innovative, machine-made, and laboratory-tested cooking fuel. The definition of green charcoal is traced back to biomass briquetting technology, which was developed in Europe, the United States, and Japan. This led to the development of the reciprocating ram/piston press, and perfected in Europe and the US. Japan independently invented and developed screw extruder technology. These screw-pressed briquettes are generally superior to ram-pressed briquettes (Mwampamba et al., 2013: 160-161).

Definition by Quality

Green charcoal has been referred to by the nature of its quality as clean fuel. Kung et al. (2015) noted that green charcoal, black charcoal in many parts of the world are perceived as a “dirty” fuel. This arises from the fact that it is dusty and often emits smoke and soot, which makes the cooking saucepan dirty.

Definition by Greenhouse Gas Emissions during Carbonisation

The purpose of Green Charcoal is to reduce the emission of Greenhouse gases during carbonisation and use. Charcoal from most earth-based kilns is produced in an oxygen-poor environment that results in the formation of products of incomplete combustion, such as methane. Charcoal production therefore affects global warming through the production and emission of greenhouse gases, such as carbon dioxide (CO2) and methane (CH4) (Chidumayo et al., 2013: 90).

Definition by Environmental Cause and Impact

From the field experimentation of cooking using green charcoal and the traditional black charcoal in Gulu City, Pabbo Town Council, and the refugee-host communities in Adjumani, the study established that the green charcoal emits a lot of heat with no smoke, making it environmentally friendly. The principal environmental purpose and advantage of briquettes influenced the definition. Generally, briquettes are produced from the byproducts of wood charcoal (i.e., charcoal dust), timber production (sawdust), and agriculture (rice and coconut husks). In the case of Wildlife Works, briquettes are also produced from twigs obtained from live trees on farms, thus eliminating the complete extraction of trees as in the traditional black charcoal production. Although a thorough life cycle analysis has yet to be conducted on the

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contribution of briquettes to air pollution and greenhouse gases (GHG) emissions, briquettes could be expected to have slightly poorer emissions characteristics than charcoal (due to the presence of binders) but perhaps better than those from firewood and other biomass lower down the energy ladder. The relative cost to the environment may be graver if waste is not utilised or properly disposed of than from the GHG emissions produced by briquettes (Mwampamba et al., 2013: 160-161). Similarly, charcoal production impacts the soil at two different levels of intensity. Intense impact occurs at the kiln site as a result of the extreme heat generated during the carbonisation process and the digging to make a pit and/or soil to cover the wood pile. Low impact occurs in the area surrounding the kiln where the wood is harvested. Soil impacts in the harvested area are probably similar to those of any low-impact forest clearing that does not result in land use change (Chidumayo et al., 2013: 90).

Green Charcoal as a Product of Waste Management

Kituyi (2004), viewing green charcoal from the end rather than the means, describes it as a product of waste management. He considers the sustainable production process of green charcoal through its value chain life cycle management to the final product green charcoal.

Rejections of Green Charcoal

This study identified the following rejections.

Physical Rejection

Among the significant physical rejections of green charcoal by users in the region are its perceived difficulty in ignition, requiring more effort or specific kindling than traditional fuels. Users also reported higher ash content after burning, which adds inconvenience in disposal. Furthermore, concerns regarding the quality consistency of the green charcoal product itself lead to dissatisfaction, as its burning performance can vary unpredictably. These rejections are in total agreement with similar observations by Okello et al. (2024).

Rejection by Colour

The immediate rejection was the colour name: “Green Charcoal”. A respondent and user of Green Charcoal noted that she had expected to see green colored charcoal and described the naming as deceptive. Participants in a workshop observed that the term ‘green charcoal’ was elusive and misleading in nature. However, Okello et al. (2024:426) argue that, although green charcoal is similar in appearance and function to black charcoal but environmentally, it is friendlier and is made primarily from agricultural waste, thus avoiding tree cutting.

Rejection by the Processing Method

Green charcoal is not charcoal made from biomass from forest plantations. It is common knowledge that Charcoal is a fuel that is produced by the carbonisation of biomass. The study observed that whereas investment in charcoal production from forest plantations is increasing in tropical regions, for the most part, biomass for charcoal production is obtained from natural forests in which natural regeneration is the main source of forest recovery (Chidumayo et al., 2013: 87). Whereas they share a common purpose of targeting environmental impacts and regenerating or restoring the environment, the nature of biomass is not similar. Unlike Green charcoal, traditional charcoal goes through the process of wood-to-charcoal (Chidumayo et al., 2013: 87). This is confirmed by Kung et al. (2015:87-88) who define green charcoal as “waste-derived briquettes” or organic waste turned into “green” charcoal briquettes.

Rejection by the Carbonising Process

Green charcoal is carbonised using a carbonizer. The charcoal in tropical countries is produced from aboveground tree biomass, implying that whole or parts of trees must be felled, and wood carbonization is commonly made in traditional kilns, of which there are many types: For example, charcoal made in earth kilns, of which there are two types: the pit kiln and the surface earth-mound kiln. The pit kiln is constructed by digging

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a pit or trench in the ground and filling it with wood before covering the wood pile with green leaves or metal sheets and soil to prevent complete burning of the wood to ash during carbonisation. The earth mound kiln is built by covering a pile of wood on the ground with leafy or herbaceous material and soil. Modified forms of the surface earth kiln may have ventilation channels, such as chimneys, as in the Casamance kiln. Other kilns are made of bricks (brick kilns) or metal (metal kilns), and although these types have the advantage of being moved from place to place, they are not in common use. The earth mound kiln is preferred over the pit kiln where the soil is rocky, hard, or shallow, or the water table is close to the surface. The pit kiln is more commonly used in Asia and America (Chidumayo et al., 2013: 87).

Rejection by Impacts of Charcoal Production on Tropical Forest Ecosystems

Uganda's Ministry of Energy and Mineral Development (MEMD), as part of its sustainable biomass strategy, defines green charcoal as charcoal produced from *agricultural residues,* including banana peels, coffee husks, rice husks, maize cobs, and other green biomass, rather than wood harvested from forests. These residues are carbonised (often in low-emission kilns or kilns like Casamance, retorts, or Hoffman technology), crushed, mixed with natural binders such as clay or cassava starch, and then pressed into briquettes. The resulting product is low-smoke, cleaner-burning, and intended to significantly reduce deforestation and indoor air pollution (Ministry of Energy & Mineral Development, 2023:37, 38).

This study established that, whereas there have been campaigns of planting artificial trees like Bamboo, eucalyptus, and Neem as a source of cooking fuel or for preparing charcoal, as far as the process is from wood-to-charcoal, it does not qualify to be green charcoal. The study appreciates the fact that the introduction of artificial trees has helped to save the natural vegetation from forest degradation and deforestation. Forest degradation is the reduction in the woody canopy cover, while deforestation is the complete loss of forest cover that is often associated with forest clearance. Degradation, therefore, represents the temporary or permanent reduction in the density, structure, species composition, or productivity of vegetation cover (Chidumayo et al., 2013: 87).

Contestations on Green Charcoal

Salma et al. (2024) consider green charcoal or Biochar not as a product but a technology for Negative emissions carbon. They noted that, production of biochar follows nature’s organic carbon pathways by removing CO2 and permanently storing it in the soil. Through the application of controlled pyrolysis, wherein biomass undergoes carbonisation to yield inert carbon, the production of biochar is a carbon dioxide removal (CDR) method, provided the biochar’s permanence is ensured. Carbon negative emissions refer to activities or technologies that remove more CO2 from the atmosphere than they release. Within the scope of pioneering negative emissions technologies, biochar serves as a focal point, directing the process of carbon sequestration and securely condensing it in a stable form for a long time. This, within the context of emissions mitigation, creates a complex entity, showing its remarkable potential, including technical feasibility, scalability potential, cost-effectiveness, carbon stability, permanence, and rigorous verification and monitoring mechanisms. The achievement of carbon reduction through biochar production emerges both as a technological advancement and an economically feasible venture, especially in the context of the evolving carbon sink economy (Salma et al., 2024:1). Biochar is therefore considered as black carbon produced from biomass sources such as wood chips, plant residues, manure or other agricultural waste products for the purpose of transforming the biomass carbon into a more stable form (carbon sequestration) (Salma et al., 2024:1).

Inclusive Definition

By production means, green charcoal can be moulded using hands, shaped using boxes, and made using fabricated machines. Green charcoal can be locally produced, with simple materials

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such as organic wastes, agricultural residues such as rice husks, peanut shells, millet stalks, cottonseed shells and stalks, banana peelings, corncobs, and coconut shells (Okello et al., 2024:424). Whereas it is important to define green charcoal by technology and process of production to save the environment, it is important to be cognizant of the indigenous or local knowledge adapted in the production of green charcoal.

UNDP (2013) also noted that there was no product differentiation between traditional charcoal and green charcoal. Therefore, at first sight, there is not much impressive about the Green charcoal.

Gulu University Interdisciplinary Definition

From the review of vast literature and primary data, this paper defines Green charcoal as a clean, eco-friendly solid biofuel produced through the carbonisation or densification of biodegradable, carbon-rich organic waste materials such as agricultural residues, forestry by-products, and household waste using efficient, often mechanised, briquetting technologies. It is designed as a sustainable alternative to traditional wood-based charcoal, aiming to reduce greenhouse gas emissions, prevent deforestation, and promote efficient energy use. Characterised by minimal smoke emission, high energy output, and improved production processes, green charcoal aligns with environmental conservation goals, waste management strategies, and climate change mitigation efforts, while also supporting socio-economic livelihoods in developing regions. It encompasses a range of terms such as biochar, briquettes, improved charcoal, and ecological charcoal, reflecting both its technological process and its environmental rationale. Clearly, this comprehensive definition corroborates related studies by Kituyi (2004), Mwampamba et al. (2013), and Okello et al. (2024), etc, that attempted to define the phenomenon “green charcoal.”

CONCLUSIONS

Northern Uganda’s cooking fuel landscape is marked by a historical reliance on firewood and traditional charcoal, driven by their affordability and accessibility, though green charcoal is now emerging as a sustainable alternative. Households, both rural and urban, typically employ a combination of fuels, a strategy influenced by cost, availability, and cultural practices. Uniquely, despite ongoing rural electrification, electricity has seen minimal adoption for cooking, primarily due to perceived high costs and safety concerns like electric shocks. While green charcoal offers a promising shift towards sustainable energy and addressing deforestation, its widespread adoption continues to face these same fundamental barriers of affordability, accessibility, and the established preference for diverse fuel sources.

Based on several studies, this study has pointed out the acceptances and rejections of green charcoal. Generally, green charcoal encompasses a range of terms such as biochar, briquettes, improved charcoal, and ecological charcoal, reflecting both its technological process and its environmental rationale. Designed as a sustainable alternative to traditional wood-based charcoal, green charcoal aims to reduce greenhouse gas emissions, prevent deforestation, and promote efficient energy use.

The "unpacking" of green charcoal in Northern Uganda is a journey from innovation to widespread adoption that is not solely a technical challenge but fundamentally a social one. While it is a promising sustainable cooking fuel, green charcoal continues to face significant contestations in the region, leading to both acceptance and rejection among users and communities. Acceptance stems from its perceived environmental benefits (reducing deforestation), improved health outcomes (less smoke), potential economic advantages (cost-effectiveness, new livelihoods), and the availability of local raw materials. However, rejection often arises from initial higher costs, perceived difficulty in ignition, higher ash content, incompatibility with deeply ingrained cultural cooking practices, and concerns over quality consistency. Challenges in access and distribution, coupled with competition from the informal traditional charcoal sector, further

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complicate its diffusion. Ultimately, green charcoal's success hinges not just on its technical merits but on effectively addressing these diverse user perceptions and practical barriers within the Northern Ugandan context.

RECOMMENDATIONS

To create a more conducive environment for green charcoal to effectively diffuse and become a widely adopted, sustainable cooking fuel solution across the Northern region, the study recommends the following measures:

- Address affordability and accessibility gaps to make green charcoal more competitive. This can be effected through subsidies or micro-financing options for initial purchases, and establishing more localised production and distribution points, especially in rural areas.
- Integrate the concept and product of green charcoal with existing cultural norms and practices. Understanding how it fits into existing cooking routines and stove types is crucial. This could involve developing adaptable green charcoal stoves or promoting cooking methods that seamlessly integrate with current practices, making the transition less disruptive.
- Enhance perceived value and usability through practical demonstrations and training to address contestations around ignition difficulty, ash content, and perceived quality.
- Gulu University, through initiatives like the UPCHAIN project, is well-positioned to act as a catalyst for change. Hence, engagement with local leaders, women's groups, and youth organisations can foster trust and facilitate knowledge transfer about green charcoal production and use in the region.

Ethical Approval and Consent To Participants

This study received ethical approval from the Gulu University Research Ethics Committee (GUREC-Reference Number 2023-641) and adhered to the Declaration of Helsinki. All participants provided informed verbal consent prior to data collection, and only those who consented were included in the study.

Availability of Data

The datasets/transcripts used and/or analysed during the current study are available from the corresponding author upon reasonable request.

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Conflict of Interest

The authors confirm they have no conflict of interest regarding the financial support, research, preparation, or publication of this article.

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