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Do Perceptions Influence the Adoption and Abandonment of Biomass Briquettes for Cooking? An Exploratory Study of Different Energy Source Users in Mbarara City

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Abstract

This study investigates the perceptions and experiences of current, former, and non-users of biomass briquettes in Mbarara City, Uganda. Using a qualitative approach, 24 participants were selected through snowball and purposive sampling, ensuring representation from all three user groups and briquette producers. In-depth interviews were conducted to capture their views, behaviours, and attitudes toward biomass briquettes. Briquette producers were interviewed to gain deeper insights into production practices, challenges, and the factors that influence the adoption of briquettes. Compared to charcoal, briquettes last longer on a cookstove, making them ideal for steaming food, which is a common practice. The lack of information about the briquettes and the briquettes taking too long to ignite are highlighted as the main reasons for low adoption and abandonment. Various factors, including food preparation habits, social connections, knowledge about briquettes, and media exposure, do influence adoption. The current briquettes produced and used in Mbarara are mainly made of charcoal residues, which makes them unsustainable and environmentally unfriendly. The frequent breakdown of machines is highlighted as a major challenge for briquette producers. Strategies such as leveraging social networks, conducting physical cooking demonstrations, improving briquette quality, using fire starters, training more producers, and utilizing social media could enhance adoption rates and reduce user attrition. The triple helix model could bridge the knowledge and skills gaps to facilitate institutional collaborations and improve the quality of briquettes. Future research should explore the drivers of briquette adoption in medium and large-scale enterprises, such as poultry farms, schools, restaurants, and manufacturing industries.

Keywords: Briquettes, Perceptions, Adoption, Waste Management, Socio-Economic factors and Barriers

1. Introduction

Over 90% of households in Sub-Saharan Africa use firewood and charcoal for cooking which is associated with social, health (Nakora et al., 2020; Tassie et al., 2021), and environmental hazards contributing to water and food insecurity (Bamwesigye et al., 2020; Mugabi & Kisakye, 2021). Besides the environmental and health impacts, the increased demand for energy in East Africa has led to an increase in the prices of fuel for cooking. In general, households are hit the hardest as high costs and limited access to sustainable energy threaten people's daily lives (Phoumin & Kimura, 2019). The increase in the prices of fuel for cooking such as kerosene, liquified petroleum gas (LPG), and electricity, is partially attributed to the increase in population, scarcity, and the ban on commercial charcoal production in some areas of Uganda (Mugo et al., 2015; New Vision 2023). In Eastern and Central Uganda, there is a slight increase in the adoption of renewable energy technologies, for example, the use of biomass briquettes in energy-saving stoves (Mainimo et al., 2022). Although Uganda is endowed with a wide range of renewable energy sources, very few of the renewable energy sources are utilized in cooking. For example, there are a lot of agricultural residues at the household level that are considered waste but could be used as raw materials that can be converted into energy by making biomass briquettes to enable cooking (Okot, 2019).

Increased access to and adoption of renewable energy, such as biomass briquettes, can reduce smoke, indoor air pollution, and carbon emissions and stimulate economic growth, thus combating climate change and global warming (Stefko et al., 2021). Evidence shows that renewable energy in general has the potential to reduce greenhouse gas emissions, and household expenditure on energy(Indora & Kandpal, 2018; Stefko et al., 2021; Yamamoto et al., 2009). Renewable sources such as biomass briquettes could also contribute to the utilization of waste/agricultural residues generated at the household level without causing a severe negative impact on the environment and human life (Chaciga et al., 2018; Fashina et al., 2019). The adoption of biomass briquettes might be influenced by individual behavior, the quality of briquettes, economic status, level of education, and social networks. The users' social networks could influence how they decide to adopt, reject, or abandon a particular energy technology. However, studies on the influence of socio-economic aspects on the adoption of biomass briquettes are limited, with none conducted in the urban setting of Southwestern Uganda. Community perceptions about the affordability, accessibility, availability and acceptability of renewable energy technologies can explain the low adoption and high abandonment rate of energy technologies (Quinn et al., 2018) as it is applied to biomass briquettes.

Generally, in Uganda, there is some level of consensus that the abandonment rate of renewable energy sources for cooking is considerably high - for some sources such as biogas standing at 40% (Lwiza et al., 2017). Yet, in most urban areas such as Mbarara, the nature of most urban housing risks the lives of the occupants. For example, the living room is often small with insufficient ventilation and is congested. This is due to occupants' need for relatively affordable housing which exposes occupants to indoor air pollution due to indoor cooking (Nakora et al., 2020; Faisal et al., 2021). Further, a study by Kyayesimira & Muheirwe (2021) focused on the health concerns of using charcoal and firewood in houses and their attitudes to adopting improved cookstoves in Bushenyi and Mbarara. They found that charcoal and firewood expose women and children to indoor air pollution, trauma, and other health hazards. It is thus not surprising that over 28,000 deaths in Uganda result from air pollution, and generally air pollution accounts for 16% of global deaths (Fuller et al., 2022; VOA, 2022). This justifies the need for such households to adopt clean cooking energy sources such as biomass briquettes. A few studies have focused on the production and distribution, and a few on the acceptability of briquettes in Kampala, Uganda's capital city (Mugabi & Kisakye, 2020). Other studies mainly looked at the drivers of household demand for cooking energy in Central Uganda (Mainimo et al., 2022) and the socioeconomic and environmental impacts of charcoal production activities (Bamwesigye et al., 2020; Tassie et al., 2021). These studies have recommended the adoption of biomass briquette use by promoting improved cooking stoves, targeting women as decision-makers on energy use, lowering the cost of briquettes, and integrating users' preferences in renewable energy development. However, there is limited literature on the cooking experiences of biomass briquette users among households in Southwestern Uganda's urban settings. Studies on adoption-related barriers and motivating factors for biomass briquettes in energy-insecure areas such as Mbarara, the biggest city in Western Uganda are generally lacking. Yet, such studies could inform interventions to address the design and behavioral-related concerns of

potential users and minimize the abandonment of biomass briquettes among households.

This study, therefore, focuses on filling the knowledge gap empirically to understand the role of current users as early adopters of biomass briquettes among households in Mbarara City and how to motivate non-users to embrace the change by adopting briquettes. This was achieved by exploring their perceptions and lived cooking experiences by comparing biomass briquettes with charcoal and other energy sources used in Mbarara. The study's focus was on early adopters, former users, non-users, and producers of biomass briquettes living in Mbarara City.

2. Study Area and Methodology

The choice of our case study was informed by an ongoing research project that aims to address sustainable development challenges in Southwestern Uganda, which includes access to affordable and clean energy (https://ucobs.must.ac.ug/). This study selected Mbarara City as the region's largest city with over 250,000 people. In addition, the study is informed by some studies that have reported energy insecurity and its effects on urban households in Mbarara (Nakora et al., 2020; Kyayesimira & Muheirwe, 2021; Abaasa et al., 2023) justifying the need for alternative energy sources which aligns well with the National Development Plan III. This was an exploratory qualitative study that collected narratives from users and non-users, including former users of biomass briquettes living in Mbarara City. The participants were living in the three sub-divisions of Kamukuzi, Kakoba, and Nyamitanga; the main divisions that constituted Mbarara when it was still a municipality (Gumisiriza & Kugonza, 2020) as shown in Figure 1 below.

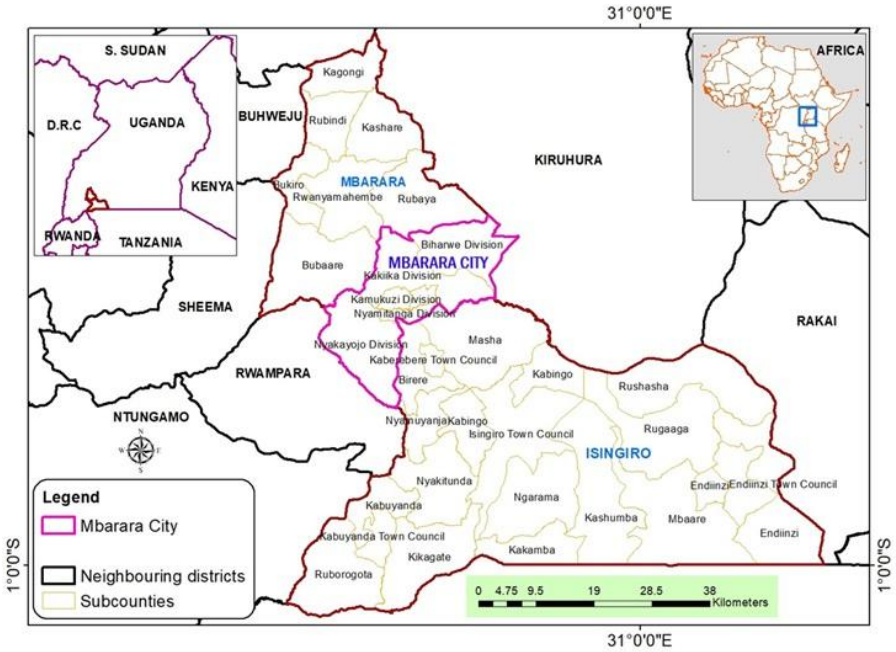

Figure 1. A map of Mbarara city showing three sub-divisions that constituted the municipality (ARC GIS, 2023)

A qualitative approach was chosen because it was suitable for understanding in detail the respondents' cooking experiences. This was accomplished by observing participants (during the interview) in their natural setting and attempting to comprehend the meaning implied by their actions. This was aimed at increasing the reliability and validity of the information collected during the study. So, by reconstructing these subjective meanings, the attained information was contextualized to reveal briquettes use-related perceptions of study participants.

In total, 24 participants were involved in this study. We conducted 20 in-depth interviews with users, former users, and non-users of briquettes in Mbarara City. All the participants were selected using the snowballing method. This technique was used to identify the different categories of participants who would otherwise not be reached without using their networks. To avoid bias, a participant made a referral of at least two potential participants from which the research team selected the next participant (based on the choice of the interviewer). Additionally, the study included four commercial producers of briquettes as participants. These were purposively selected from a total of 6 known commercial producers in Mbarara City, and the sample is considered representative. Saturation, the point at which no new information is reported from participants, is the criteria for sample size in qualitative research. This was the determinant for our final sample size, usually a smaller number of participants (Ugalde et al., 2017; Wutich et al., 2024). The saturation point was achieved by the 20th participant in the first category (users, former users, and non-users) combined. The 4 commercial producers gave breadth to further understand some of the participants' experiences as users, former users, and non-users. The study used an interview guide. Generally, the study collected narratives in which participants shared their lived experiences with cooking, as related to the adoption and non-adoption of biomass briquettes, with the research team. Interviews were conducted in October 2023 from households that use different energy sources and selected commercial producers. Data was analyzed based on the themes from the research question and responses from the participants.

The study followed the ethical procedures and received approval from the Mbarara University Research Ethics Committee (MUST-2023-1275). Other ethical principles, such as doing no harm, protecting the participants, obtaining written informed consent, and ensuring confidentiality, were respected throughout the research process. The interviews were conducted in a conducive environment where participants were free to express their views and share their cooking experiences of using different sources of energy.

3. Results and Discussion

This study presents comparative experiences of the different study participants using different sources of energy in cooking, especially the use of briquettes from users, former users, and users of charcoal, complemented by the voices of the briquette producers.

3.1 Demographic Information and Sources of Energy for Cooking

Table 1. Demographic characteristics of study participants (Field Data, 2023)

Average age (years)	35.5
Level of Education	
Primary	6
Secondary	3
Tertiary or university	14
Location (sub-division)	
Kamukuzi	8
Kakooba	12
Nyamitanga	4
Average household size	4-5
Energy source for cooking	
Biomass briquettes	9
Abandoned briquette use	3
Liquefied petroleum gas (LPG)	3
Firewood	2
Charcoal	14

The age of the producers of briquettes is not captured in this data category. From Table 1 above, the participants' levels of education also include the producers. The majority of participants are from Kakooba sub-division. The average household size of the 20 participants (i.e. excluding the briquette producers' household size) was 4.7 members. The majority of these participants use charcoal, although some have used biomass briquettes, about a third of them have abandoned their use in cooking. A smaller number use Liquefied Petroleum Gas (LPG) to complement their cooking and a few use firewood as compared to the biggest number of those who use charcoal. The results are in agreement with previous studies which revealed that close to 80% of urban households use charcoal for cooking (Alinaitwe & Bergland, 2024; Nakora et al., 2020; Namazzi et al., 2024). None of the participants in this study reported the use of solar, electricity, and biogas in cooking highlighting the low-to-non-adoption of such renewable sources of energy with a cooking application potential. Participants in this study were asked to estimate the percentage of households in their immediate surroundings that use briquettes for cooking. Based on responses from 7 participants who estimated the percentage, about 4.6% use briquettes for cooking. The other 13 participants did not give an estimation. These findings agree with previous studies that report low adoption of alternative energy sources in cooking for example, 1.5% for LPG, 2% for electricity (International Energy Agency, 2023; Mbarara District Local Government, 2017; Uganda Bureau of Statistics, 2022, 2024).

While the abandonment of briquettes is not very pronounced in the existing literature, it is evident that households that initially used briquettes have started to abandon them. Approximately 3 out of 9 households that had adopted briquettes in cooking have abandoned their use in our study. Some of the major factors stand out for abandonment: poor quality, limited access, not being seen in visible spaces compared to charcoal or firewood, and that briquettes are commonly used by other people living in their surroundings. Abandonment of

briquettes was reported by former users, non-users, and producers of briquettes in this study. A previous study also reported the abandonment of biogas projects that provided energy for cooking in the districts of Luwero and Mpigi in central Uganda (Lwiza et al., 2017). Grey literature has alluded to the abandonment of briquette use, lack of market, and access to information about the use and benefits of briquettes in Uganda (Abdullah Ibrahim, 2020; Emwamu, 2021; The Independent, 2023). An empirical study on cooking technologies specifically cookstoves in central Uganda by Katutsi et al., (2023) noted that abandoning improved biomass cookstoves is mainly attributed to their poor quality. It is important to enhance the quality of cooking technologies, for example, improved biomass cookstoves, biomass briquettes, and solar technologies where applicable, to achieve sustained use, and social acceptance, thus minimising their abandonment in Uganda. This calls for addressing issues relating to the quality of alternative energy sources to give users a good cooking experience, as it is with conventional energy sources.

In general, there is the abandonment of alternative energy sources, partly because they are considered less efficient and new in users' contexts and opinions when compared to conventional energy sources such as charcoal and firewood. In addition, not knowing the environmental and health benefits of using clean energy contributes to less adoption and abandonment of briquettes. In this study, some participants alluded to the negative health outcomes of using charcoal, indicating that they had some level of knowledge about the health consequences associated with using charcoal.

3.2 Cooking Experiences: Insights from the Users, Non-users, and Former Users of Briquettes

The participants in this study highlighted the commonly prepared dishes in their households. While the focus was put more on food, the study also highlighted some of the commonly prepared types of sauce or soup in the households where the interviews were conducted. The dishes include bananas, rice, Irish potatoes, potatoes, cassava, millet, posho (prepared from maize flour), and pumpkins. The most prepared sauce included dry and fresh beans, peas, meat (of different types), ground nuts, and a few household-mentioned fish. These were commonly mentioned in the interviews, although other dishes and sauces are prepared in the context of Southwestern Uganda. The dishes that take a short cooking time to prepare can be cooked using LPG, as was the case for some households that prepare breakfast and sometimes warm the food.

It is evident from the findings that users of briquettes and non-users have almost the same combination of food dishes that they prepare often. From the findings, the following dishes are commonly prepared by households: bananas, rice, millet, maize, cassava, potatoes, yams, pumpkins, with dry beans, fresh beans, fish, meat, groundnuts, and porridge. This is well linked to the energy sources commonly used which the study cited as charcoal with few households using firewood in Mbarara City. Other households use alternative sources of energy e.g., briquettes, LPG, and none of the households surveyed mentioned using electricity from the grid or solar for cooking. This is an indicator that there is low adoption of alternative sources of energy in Mbarara city that are considered clean according to

international standards. Existing literature further shows that most households in urban areas use charcoal. For example, a study by Nakora et al., (2020) noted that 77.3% of the population in Mbarara City and Oteu et al., (2024) found that 79.3% of the population in Mukono use charcoal for cooking. This is in line with the Uganda Energy Policy Review report which found that 82% of the population in Kampala city uses charcoal, and a smaller percentage (7.6%) uses LPG and electricity for cooking (International Energy Agency, 2023). Since the cooking of most dishes does not influence the choice of an energy source, it makes briquettes adoptable in preparing any dishes in Uganda based on the commonly available and prepared dishes as identified by this study. Our study shows that 14 out of 20 households use charcoal for cooking, accounting for 70% use of charcoal in the three sub-divisions where the study was conducted. We affirm that a significant percentage of households in most urban areas in Uganda use charcoal for their major cooking activities.

It is worth mentioning that an increase in prices for different sources of energy, especially charcoal, was commonly mentioned throughout the interviews which were conducted. The price of a bag of charcoal toward the end of 2023 in Mbarara City ranged between 65,000 ($17.6) and 100,000 ($27.0), depending on the quality and size. The good quality bag of charcoal lasts between two weeks and 1 month, the midpoint being three weeks (approximately 21 days) for an average household of 4-6 people. Participants mentioned that between 3 and 4 months preceding the data collection exercise, the prices of charcoal increased by a range of 10,000 ($2.7) and 15,000 ($4.05) for each bag. According to the 19 households that specified their current expenditure on charcoal, the average price for a bag of charcoal was found to be 75,500 Ugandan shillings compared to range of 30,000 to 40,000 Uganda shillings for those using briquettes in Mbarara City. Using briquettes could reduce energy expenditure by more than half of their current expenditure based on the charcoal prices and duration of the bag of charcoal for cooking at a household level. The increase in energy prices, especially for charcoal, is a result of the high demand, and energy insecurity reported by previous studies (Abaasa et al., 2023; Kyayesimira & Muheirwe, 2021; Mugo et al., 2015), and the ban on commercial charcoal production in Uganda implemented by the National Forestry Authority (NFA) and the National Environmental Management Authority (Wekesa et al., 2023). This study highlights how overreliance on charcoal has a significant impact on its prices in Uganda and justifies the need to diversify energy sources for households to enable users to switch from one energy source to another, motivated by factors such as affordability. This could contribute to addressing the problem of energy insecurity in terms of availability, accessibility, affordability and acceptability according to Cherp & Jewell, (2014), general and indoor pollution in Mbarara City (Nakora et al., 2020). The lack of diversity in energy sources demonstrates a high magnitude of energy insecurity which requires urgent redress to save the environment and minimise climate change effects, and improve the health and well-being of the population in Uganda.

This study revealed that there was an abnormal increase in the prices of charcoal compared to the prices of other products in general. Some households resorted to the adoption of alternatives such as wood, having realized that the cost of charcoal was very high. While this study did not further explore this aspect, it can be noted that from the grey literature, price

increases associated with charcoal for cooking in Uganda are a result of scarcity as forecasted in the National Charcoal Survey (Mugo et al., 2015). This study conceptualized this as a visible indicator of energy insecurity in Mbarara which could apply to Uganda in general. Additionally, the decreasing source of raw materials for charcoal production could have equally contributed to price instability. Moreover, the ban on commercial charcoal production is being implemented in most parts of Uganda (The New Vision, 2018; Wekesa et al., 2023) could have contributed directly and indirectly, as other areas also depend on charcoal produced from western Uganda. In other areas, such as Kampala, the capital city of Uganda, prices range between 100,000 ($27.02) and 140,000 ($37.84), and charcoal is not easily available. The increase is mostly evident in charcoal, compared to other energy sources such as firewood, briquettes and LPG. This situation is a characteristic of energy insecurity which is usually exemplified by a lack of and limited access to, availability, affordability and acceptability as described in previous studies (Abaasa et al., 2023; Cherp & Jewell, 2014; Kyayesimira & Muheirwe, 2021).

Most households that participated in this study revealed that they prepare more than two meals per day: lunch and supper as the main meals. Other meals that the household considers soft or fast such as breakfast or evening tea are prepared in addition. Accordingly, households that use more than one source of energy use the alternative to cook lighter meals such as breakfast, warming certain dishes, or evening tea. In general, a few participants who used LPG in this study mostly used it to cook lighter meals or meals that take a very short time to get ready. Most users of an alternative source of energy identified a particular use linked to faster or quicker cooking. From this study, it is observed that only one household prepared one main meal (supper) and a lighter or softer meal on most days, apart from weekends. There is no major difference between energy source use with a meal being prepared, although alternative sources such as LPG are considered the best alternative for fast meals or households that prepare one main meal. Our findings are a confirmation of what has been reported by a previous study on the low adoption of LPG which stands at 1.5% in Uganda (International Energy Agency, 2023).

A few households that currently use or have used briquettes before for cooking described some of the advantages of briquettes as lasting longer on the stove compared to charcoal. These include being good at preparing dishes that require longer periods, for instance, more than 4 hours of cooking, producing less smoke, while others revealed that briquettes have less smoke. Some of the dishes that necessitate long periods of cooking include dry beans, dry peas, and meat, and some households prefer to prolong steaming [commonly referred to as “okukomeera” in the local dialect - Runyankole] their food to keep it hot until the time of having the meal. This is very common with bananas, and posho or mingled maize flour. There is no appropriate time for prolonged steaming, as the purpose is to keep it hot; this entirely depends on when the meal will be taken. A study by Asada, (2019) among households in Kampala found that prolonged steaming takes between two to four hours and cannot be done using LPG, which partly explains why there is low adoption of LPG for cooking among households. In this study, we have demonstrated that the duration of steaming is determined by the difference between the time when the meal is prepared and when it will

be eaten. In addition, prolonged steaming is a contributing factor to energy insecurity as this increases the demand for energy in energy-constrained settings.

Prolonged steaming requires a lot of energy which translates into more expenditure for households that prefer steamed food. To reduce household expenditure on energy for cooking and prolonged steaming, households that produced their briquettes highlighted that briquettes are a feasible solution. One of the participants mentioned having attempted to make briquettes for home consumption to reduce the expenditure. However, the participant reported that the quality was not good as the briquettes produced a little more smoke, took long to catch fire, and were slow to cook. This study highlights the willingness of briquettes users to make their briquettes to reduce their expenditure on energy. Throughout the study, none of the participants mentioned having been trained in making and using briquettes in Mbarara City. While we cannot conclude that there is no training for briquette users and producers, there is a need to reach more potential users and producers with such pieces of training. The study demonstrates how the lack of training compromises the quality of the briquettes and their availability as some of the factors limiting their adoption and sustained use for cooking. From one of the producers in our study, it was revealed that some producers offer training. Among those who are trained, a few continue into active production while others quit. The majority of the trainees consider production for home consumption, while a smaller number go into large-scale production for commercial purposes. In this study, we argue that massive training could lead to the sustained production and use of briquettes and improve their quality in Mbarara city and beyond. We highlight the potential of the triple helix model in bridging the knowledge and skills gap for commercial producers and users of briquettes. Here, the university, industry "commercial producers", and the government could collaborate to train (Cai & Lattu, 2022) and interest more people in producing high-quality and adopting briquette use in cooking. To safeguard producers from abandoning the production of briquettes, studies highlight the importance of technical skills such as the ability to repair equipment, as reported by Lwiza et al. (2017). In this case, Mbarara University of Science and Technology in this collaboration, could offer through internships and community placements as part of the academic training to the students in different disciplines (Horcea-Milcu et al., 2024; Mbarara University of Science and Technology, 2022). In the triple helix model, the three collaborators could jointly fund the training, as an equally shared responsibility. The funding, policy, research and infrastructure models could also be guided by the matrix provided by (Akinyoade et al., 2014; Kariuki et al., 2018), as shown in Table 2 below.

Table 2. Triple Helix Model in renewable energy development (Kariuki et al., 2018)

Economic Foundation	Government	Industry	University
Skills Development	High	High	High
Research	Moderate	High	High
Policy	High	Moderate	Low
Funding	Moderate	High	Low
Infrastructure	High	Moderate	Low

Relatedly, some users of briquettes mentioned that in general, briquettes take a long time to catch fire (estimated above 30 minutes by participants), sometimes they are of poor quality, and hence slow down and delay the cooking. In addition, current briquettes produced and used in Mbarara City are susceptible to incomplete combustion, and users consider this as one of the quality-related factors that discourage the sustained use of briquettes among households. This partly explains why some of the former users prefer using conventional sources such as charcoal which is mostly used for cooking, compared to briquettes. For briquettes to be continuously used, users look out for basic functionalities and efficiencies based on their experience of using charcoal and firewood. Users compare the alternative energy sources with the conventional sources and assess the level of efficiency before adopting or abandoning, especially if the source of energy doesn't match the expectations of the users. Some of the producers in this study mentioned their involvement in producing fire starters to reduce the use of charcoal in the initial lighting of the briquettes. However, using fire starters is not pronounced among users, not even the former users. There is little to no awareness of alternative ways of lighting the briquettes that this study highlights as fire starters. Although a network of wholesalers of fire starters exists, the fire starters remain unpopular among current users of briquettes. There is no existing literature that alludes to the lighting of briquettes, the use of fire starters, and compares the efficiency of briquettes with charcoal. This study contributes to the literature on alternative energy use and ignition time in Uganda. Producers in Uganda could benchmark from a study by Sanka et al., (2024) that tested different feedstock compositions. For examples, briquettes made from faecal sludge took longer than 20 minutes to ignite a fire compared to those made from charcoal and saw dust (Sanka et al., 2024).

Households highlighted possessing a kitchen "a place where almost all the cooking is done for most households in Uganda". Although some households did not have a kitchen, most of those who participated in our study had a kitchen. The households that did not have a kitchen do most of their cooking from the veranda or house-shade, especially when they use charcoal for cooking. This is aimed at reducing smoke inside the household. However, whether the household has a kitchen or not, smoke still finds its way to the main house, causing indoor air pollution, especially when polluting sources of energy are used such as charcoal, firewood and briquettes in their current quality. Most briquettes produced in Uganda, mainly in Mbarara city are made of a combination of charcoal residues and other biodegradable materials, which contributes to some emission of smoke causing indoor air pollution in households. The emission could be a result of a low extent of carbonization and the poor missing ratio of charcoal to binder i.e. clay as the most used binder material. This compromises the quality of briquettes in the opinion of the users and could contribute to a negative attitude toward using briquettes among non-users. There is a need to venture into alternative materials recommended by (Ayaa et al., 2025; Lomunyak et al., 2024; Sanka et al., 2024) that don't emit smoke or have reduced smoke content compared to the briquettes that are currently produced in Mbarara City. In this study, environmental implications are evident as briquette production uses charcoal dust which is obtained after cutting trees and burning the charcoal. In addition, there is a need to establish national quality standards for briquettes to ensure some level of uniformity of the energy source and a study Lomunyak et al. (2024)

has provided guidelines that producers in Mbarara could benchmark from.

There were compelling reasons for not using briquettes from the participants' view. Most households that have not used briquettes presented diverging views about their knowledge of briquettes. Most of the participants revealed that they had never heard about briquettes, others argued that they had seen them, but never knew what they were used for, while others had heard about briquettes but had never used them. A few participants mentioned that they had witnessed their neighbours using briquettes, while others disclosed that even their neighbours did not know about the briquettes. We have demonstrated that the role of social networks in open communities compared to closed communities' social interaction is limited by wall fences, not knowing what happens in the immediate neighbouring households. There is a potential for adoption among non-users who mentioned that they know their neighbours here referred to as "social networks" who use briquettes for cooking. Through social networking and sharing experiences about briquettes, compared to where social networks don't exist. In this paper, we argue that this would be possible if the quality of briquettes is compelling so that the users share their good experiences of cooking using briquettes with their social networks, who are non-users (He et al., 2022; Nientimp et al., 2024). Such revelations on briquettes pave the way for more strategies related to enhanced adoption which are discussed in the next section 3.4 of this paper.

One of the participants reported having started using briquettes in 2016 and later abandoned them in 2021. The participant was motivated by a cousin who was using briquettes for cooking. The housemaid informed the participant after realising that they were cheaper daily (spending 2000 Ugandan shillings) compared to using charcoal (spending 3000 to 4000 Ugandan shillings). Other factors were the longer duration of briquettes holding heat, lower carbon monoxide emissions, lower chances of causing suffocation and her husband's support after suggesting that they start using briquettes in cooking in their cooking activities. It is not hard to learn using briquettes, not much training is required on how to use them and a simple explanation from the producer or retailer is enough to enable the user to cook efficiently. From the interview, two quotations that support and motivate the adoption of briquettes are derived from this participant:

"...less money is spent on purchasing briquettes than charcoal because they are made from locally available materials".

"Briquettes are more effective in terms of retaining heat for long, with lower chances of carbon monoxide emissions, and fewer chances of causing suffocation compared to charcoal" (R19, 35-year-old former use of briquettes, 2023).

The major reasons for abandoning briquettes were the delays associated with using them for cooking, having gotten busy thus coming late in the evening, and the desire to cook faster. A quotation from this participant below clarifies why the household abandoned using briquettes in 2021.

"... stopped using briquettes for cooking at home because we became too busy at our respective places of work. We come back home late in the evening and cooking with

briquettes takes some reasonable amount of time, so, we resorted to using charcoal that fastens the cooking process" (R19, 35-year-old former use of briquettes, 2023).

In comparison, the challenges associated with using charcoal include smoke containing carbon monoxide poisonous gas and soot (accumulating on the roof, ceiling, curtains). Lighting a charcoal stove presents an additional burden such as using polythene bags which produce unpleasant smells, gases and others who use paraffin to quickly light charcoal which is costly as it adds to the expenses associated with using charcoal. A study conducted in Ethiopia found a higher burden of respiratory illnesses affecting 47.6% of women using charcoal for cooking. Respiratory complications were common among women who were housewives, lacked formal schooling, had seven or more household members, had no ventilation, and did indoor cooking (Shanko et al., 2022). The health effects of using charcoal are in line with the findings of a study by (Nakora et al., 2020) who found that lack of ventilation and indoor cooking are major contributors to indoor air pollution, a leading cause of respiratory illnesses. In this study, we have demonstrated that the use of charcoal for cooking among households presents an additional burden to Uganda's already poor air quality indices which are between 7 to 10 times higher than WHO recommended standards reported in the existing literature (IQAir, 2022; Onyango et al., 2019, 2024). The burden resulting from the use of polythene bags and kerosene to light the charcoal stove is what this study further demonstrates. While users of briquettes light them using the same techniques, others use fire starters much as these are not popular and widely used. Households in Mbarara City using polythene bags and kerosene are likely to experience a higher burden of respiratory illness.

3.3 Complementary Views from the Producers of Briquettes

The producers affirmed that the use of briquettes has been embraced by some users amidst mixed reactions, responses, and attitudes. The production of fire starters is a possible remedy to eliminate the use of charcoal to light briquettes. The current producers of briquettes also produce or partner with producers of improved biomass cookstoves to achieve high energy efficiency in cooking using briquettes. Whereas some producers make briquettes from recycled waste, most of the production uses charcoal residues, and sawdust complemented with clay, soil, and molasses. This study highlights the environmental unfriendliness of producing briquettes from sawdust and charcoal residues as a threat to the environment, as the process drives the demand for wood, and charcoal to get the by-products. It is possible to use agro-waste and other feedstocks recommended by Okot, (2019) which are plenty in southwestern Uganda. Moreover, environmental, sanitation and health concerns have been reported in Mbarara over waste mismanagement at the Kenkombe dumping site in Kakooba where over 200 tons of waste are dumped daily (Gumisiriza & Kugonza, 2020) more than half of it has the potential to be used as feedstock for briquettes. With an alternative purpose such as briquette production, such a menace could be dealt with sustainably. This will potentially replace currently used raw materials in making briquettes; charcoal residues and sawdust which are not only unsustainable but are also competed for other uses. The current briquettes are mainly made of charcoal residues, and the sustainability of the feedstock is compromised since it requires producing more charcoal to produce more residues. This will

make briquettes qualify to be biomass briquettes, meeting most of the parameters of environmental sustainability, and translating into energy security.

The use of manual machines or labor, with less-modern production equipment, has a bearing on the quality of briquettes. The producers reported constant breakdowns of the machines. The breakdown affects production as well in terms of quantity. It is possible to improve the machinery and, where possible, automate the production process with advancements in machines which eventually could increase the quality, quantity and minimize equipment breakdown currently experienced by producers in Mbarara city. This could require working jointly with a wide range of disciplines, such as mechanical, electrical, and software engineering, and non-engineering disciplines such as business, economics, and physics. This could lead to innovative, well-thought-efficient machinery that could enhance the production of briquettes. This could be complemented by working with established communities of commercial producers to identify the feasibility of integrating more advanced machinery to support the mass production of briquettes to meet the market expectations when the need arises. The produced briquettes vary in size, shape, and weight. Figures 2 below show the most common shapes and sizes produced in Mbarara City.

Figure 2. Some of the shapes of the briquettes produced in Mbarara (First author, Dec 2023)

Most of the users of briquettes in Mbarara city are educated with a qualification above secondary. The educated consider many factors before deciding to use briquettes such as the level of cleanliness, smoke emitted, and the amount of money they are likely to save compared to using charcoal. Women tend to realize much more need to adopt cleaner energy for cooking, such as briquettes, compared to men. One of the respondents during the interview said:

"*...customers are majorly educated, they have advanced minds that can compute fast, can easily do research, and calculate the amount they are likely to save when they use briquettes".*

"...women know the hardships of the kitchen such as smoke, touching the charcoal and later touching utensils which makes them dirty. Women need clean and less smoky briquettes" (Producer A, 2023).

Another producer highlighted some of the strategies to promote the adoption of briquettes, such as door-to-door marketing and the use of social media. It was noted that most users of briquettes are those who interacted with the producer during the door-to-door initiative, complemented with a physical demonstration of using briquettes before the COVID-19 pandemic, with most users preferring them for chicken brooding to cooking. The door-to-door initiative/intervention was affected by the lockdown which started in March 2020 due to COVID-19. What was common among the responses of the two producers was the significant importance that educated people attached to the adoption of briquettes. In addition, the users living in urban settings adopt briquettes than those living in rural settings. Briquettes are not widely adopted due to the low sensitization of the public and different negative perceptions, such as buying briquettes in kilograms as opposed to charcoal which is sold in bags, sometimes influencing users to abandon their use.

An additional challenge is the bulk of the residues in terms of ash which is produced by the briquettes. Users compare the quantity of briquette residues in the form of ash residues from charcoal and consider it an adoption barrier. Briquettes disintegrate into small particles after burning, and the quantity of ash remains almost a quarter of the size of the briquette. This is closely associated with the materials used, such as clay and soil which do not disintegrate. It is evident from this study that the materials used impact the quality of briquettes and contribute to less adoption and abandonment among users.

Related to the above are the locally fabricated machines for making briquettes which do not meet the recommended standards according to some of the producers in this study. The machines are characterized by constant breakdown which affects production capacity and sometimes leads to temporary halting of production. In the long run, this impacts the availability of briquettes to users. Below is a quotation from this producer alluding to this challenge.

"...machinery is also another challenge, it disturbs [breaks down often] *us a lot because they are fabricated from within here, I don't know if they are standard machines. They limit our consistency in production due to breakdowns now and then requiring repairs. They also limit*

marketing, if you are a well-known producer, users can demand briquettes and you don't have what to supply them, it is so disappointing" (Producer C, 2023).

There is a need to support production firms with modern equipment to keep them in production. The role of the government and NGOs that are interested in a low-carbon economy come in handy. Interventions to support adoption need to start with empowering the producers to improve the quality of the briquettes, and benchmarks are provided in studies from the East African region (Ayaa et al., 2025; Sanka et al., 2024; Towett et al., 2024).

3.4 Potential Strategies to Enhance Adoption of Briquettes

Inferring from the study findings, the presence of a network of current users presents a greater influence on the adoption of biomass briquettes. The current users live in the same community as non-users. Through social interactions, and sharing experiences, which is a common practice in most African societies, non-users could get interested in piloting how briquettes cook, and they could compare with conventional sources of energy. The interaction may be more valuable in areas slightly outside the concentration of the city such as peri-urban areas where the social connections are tight than in typical urban areas where people have wall fences. The wall fences hinder interactions between neighbours to the extent that each of them will never know what takes place in their immediate surroundings. This situation in typical urban areas could hinder interaction as people belong to different social classes and may choose to interact or not with a particular social class.

While this potential solution is presented with a sounding hindering factor, access to mobile phones in Uganda currently stands at 67.7%, those with mobile internet connection account for 27.0% and those using social media were only 5.3% of the total population by January 2024 (Digital Uganda, 2024). There is a potential to heighten sensitization about clean energy using social media as a virtual social network which has limited barriers. Although the literature indicates that access to social media overall is at 5.3%, users with mobile internet are likely to see online content whether they use social media or not. In general, social media and using electronic information could reap big for renewable energy adoption and use campaigns in Uganda. Well-developed e-content on renewable energy using various social media platforms could drive the change.

The increase in the price of charcoal, a conventional source of energy presents an opportunity for briquette adoption in Uganda. As charcoal becomes scarce and more expensive, the briquettes could gain penetration into communities that already consider charcoal expensive. This requires mass production to meet the demand in case there is a boom in demand. Therefore, supporting current producers and establishing more cottage industries to ensure that there is sufficient production of biomass briquettes is a prerequisite. This would contribute to stability in the prices of briquettes so that prices do not follow the same trend as skyrocketing charcoal prices that are currently evident in Uganda.

From the views of briquette producers, it can be concluded that the use of door-to-door interventions and physical demonstrations is an appropriate intervention to raise awareness and confirm that briquettes are a viable alternative for household energy needs. In addition,

training more people to produce, and others to sell them, and implementing strict laws against tree cutting for charcoal production could make briquettes an alternative among households in Mbarara City.

4. Limitations of the Study

This study acknowledges the following limitations. (i) The study was conducted in one city in western Uganda and was a qualitative study. The results on abandonment and adoption are context-specific and can be generalized in studies with a larger sample size. (ii) The study did not include an equal number of users, non-users and producers, which may also limit the generalizability of the findings. We recommend that future studies consider recruiting the same number of participants from each category to be able to rank their perceptions and quantitatively analyse them using statistical parameters. Future studies could follow former users to identify the major factors contributing to abandonment in Mbarara City in depth and give a balanced view on abandonment. There are possibilities for a comparative study in different cities to identify the differences and similarities. (iii) The study could not confirm the level of quality of briquettes produced in Mbarara City. We report that briquettes were not of standard quality. We relied on the responses from the users, former users, non-users, and producers. Since we did not conduct any techno-economic assessments and quality tests, future studies could consider assessing technology and economic-related parameters to properly evaluate the production costs and quality of briquettes in Mbarara. Additionally, these parameters could be studied concurrently with attributes that may influence potential users to adopt and sustainably use briquettes for cooking.

5. Conclusions

This study demonstrates that long hours of cooking among households in Mbarara City require more sustainable energy sources and are linked to high energy demand and prices. Households that cook in the main house are more exposed to indoor air pollution. Community-centred approaches such as physical demonstrations and cooking experiments to promote briquettes have shown the potential to increase knowledge and adoption about briquettes. The network of current users presents a potential to promote briquettes among non-users. The cost of energy for cooking, comparatively, presents briquettes as cost-effective compared to charcoal and wood.

There are mixed reactions to price changes in charcoal and wood. There is a need to address how to start the fire while using briquettes, since it demands the initial use of charcoal. While the husbands mainly make decisions on the acquisition of energy, the wives decide how the energy will be used in the household, although in female-headed households, the women have the mandate to make decisions on both. Interventions to promote the adoption of briquettes demand the involvement of both users and providers at the household level. This study has provided evidence in the academic literature about the abandonment of biomass briquettes by households in Mbarara City, which could be avoided. The results of this study have confirmed that, compared to other regions in Uganda, southwestern Uganda is not an exception to the low adoption of alternative energy sources such as briquettes. This use of similar or related interventions could reverse this problem based on the available evidence,

setting, and feasibility of interventions, such as cooking demonstrations to non-users.

Adoption of briquettes is influenced by social, economic, and cultural factors, including the duration a dish takes to be ready, social connections, and knowledge about its use and availability. The use of social media platforms through which potential users can access information regarding briquettes contributes to a big change regarding these factors. The quality of briquettes highly influences continued use and contributes to the reasons for abandonment, and the triple helix model could bridge the knowledge and skills gap through the training of producers. Future studies could explore drivers of briquette adoption in medium and large enterprises such as hotels or restaurants, schools, and production plants that have transitioned from conventional energy sources. In addition, their perceptions about the nature of the energy value chain could be explored. Additional studies could analyse trends in charcoal prices to improve our understanding of price changes and the long-term economic benefits of briquette adoption using larger samples. This will contribute to a better understanding of the economic benefits of adopting briquettes in Southwestern Uganda.

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Conceptualisation, methodology, data analysis, formal analysis, data curation, validation, original draft, review, and editing, funding (JA); conceptualisation, methodology, formal analysis, review, and editing, supervision, and funding (IK); data collection tools review, data collection, review of the draft (IrK, AR); supervision, review and editing of the manuscript (DKO). All authors reviewed the final version of the manuscript.

Informed consent

Obtained.

Ethics approval

The study was approved by the Mbarara University Research Ethics Committee and adhered to ethical principles contained in the Helsinki protocol.

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