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The Production and Adaptability of Carbonized Briquettes from Banana Peels in the Banana-Staple Society in Kampala, Uganda[1]

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Abstract Bananas are grown and consumed in large quantities in Uganda and have been a staple food that is socially and culturally important. Additionally, the leaves and fiber are used for various purposes such as cooking and fulfilling other daily necessities. Banana peels are used as a biomass briquette material in place of charcoal, which is currently used as the primary cooking fuel; this has been the case since the late 2000s in Kampala, the country's capital. This study examined the suitability of carbonized briquettes made from organic waste in a community where bananas are the main food source in Kampala. Through a fieldwork-based survey, production practices, material accessibility, and expansion of production are explored. It was discovered that briquette material is available all year long. Briquettes can be produced using widely available materials, and producers actively share production methods with each other. Since bananas and other steamed and stewed foods are common, briquettes are a convenient substitute to charcoal. With the rise of charcoal prices, briquette production and its use as fuel for cooking is expected to spread. Briquettes could become a new cooking fuel option or partial substitute and help reduce charcoal consumption and reliance on woodfuel.

Keywords: Alternative fuel; Biomass briquettes; Local diet; *Matooke*; Waste management.

Introduction

Bananas (*Musa* spp.) are widely produced and consumed in Uganda, East Africa. Their production was reported to be 8,326,000 tons in 2019 (UBOS 2020). As a culturally important staple food in the region, bananas are widely grown in Central and Western Uganda (Sato 2012). They are wrapped in banana leaves, steamed, mashed, and cooked to prepare a dish called *matooke*,[2] and served with a tomato- or groundnut-based sauce. The Ganda people (Baganda),[3] who mostly live in Central Uganda, have been eating *matooke* prepared in this way for over 100 years (Roscoe 1911). Although the consumption of rice and maize flour has increased in recent years, bananas remain a staple food, and are not only widely consumed in the region but also have high social and cultural values.

In addition to the banana fruits, banana leaves, fiber, and pseudostem are used

for various purposes, such as cooking and fulfilling daily necessities (Sato 2011; Watsemwa 2017). In contrast to cereals, which are milled before transporting to cities, bananas are transported to urban areas in bunches, with the skin and stem unremoved. Consequently, urban kitchens produce a large quantity of banana peels and other banana-related waste. Studies on waste segregation in Kampala showed that banana peels, similar to potato peels, are more separated compared to other types of waste in order to use as livestock feed and field compost (Ekere *et al.* 2009; Banga 2011).

The most common method of cooking bananas and other staple foods in Uganda is to steam them, and woodfuel, such as firewood and charcoal, is used as the heat source (Asada 2019). In Uganda, as in other African countries, woodfuel is the main cooking fuel. Particularly in cities, charcoal is the main fuel source. Food and fuel for cooking are very relevant because most foods, especially carbohydrates, need to be heated. Carbohydrates must be gelatinized in order for humans to digest them, which needs heat and water. The transition to clean and modern cooking fuels, such as LPG and electricity, has been an issue in the tropics since the 1970s due to concerns over the depletion of forest resources (Barnes *et al.* 2005). In contrast to Asian and Latin American countries, in many African countries over 70% of households continued to use woodfuel as their main cooking fuel in the 2000s, and its consumption is expected to remain the same or increase (Araya *et al.* 2011). A previous study mentions that people in rural Mexico did not transit heat source from firewood to LPG. One of the main reasons was that it was not suitable for cooking tortillas, their main food (Masera & Saatkamp 2000). In addition to the high cost of LPG and electricity, woodfuel is still preferred for cooking in Kampala because it produces heat for a lengthy period of time, making it ideal for simmering rather than rapid boiling (Asada 2019).

Since the late 2000s, African countries have implemented Biomass Energy Strategies (BEST) to increase the consumption efficiency of existing biomass fuels and promote the efficient and sustainable use of other biomass resources instead of woodfuel (Owen *et al.* 2013). In 2013, Uganda's Ministry of Energy and Mineral Development (MEMD) released the "BEST 2013" initiative to promote the use of improved cookstoves, efficient charcoal production technologies, and utilization of non-wooden biomass fuels (MEMD 2014).

Biomass briquettes, compacted solid fuels made from biomass residues, are an alternative to firewood and charcoal. In Uganda, briquettes have recently been produced from organic wastes, such as banana peels, from urban areas, mainly Kampala. Previous studies on briquettes made from banana peels noted their effectiveness in Thailand and other Southeast Asian countries (Wilaipon 2009; Mopoung & Udeye 2017). The introduction of biomass briquetting to Africa was attempted in the 1980s, but most of these attempts failed to take root. According to Eriksson & Prior (1990), biomass briquettes, which are made from agricultural waste and forestry residues generated in rural areas and reflect the cost of production, were expensive for the local population, who continued to use firewood collected in the forests around settlements and even in urban areas where charcoal are able to be purchased at much lower prices than currently. Tumutegyereize *et*

al. (2016) found no differences in burning performance between briquettes and charcoal; nevertheless, briquettes were not widely used in Uganda, as they were more expensive than charcoal. However, the price of charcoal in Kampala has tripled in the last decade (Tenywa 2021). Recent studies have indicated that the demand for briquettes as an alternative to charcoal is increasing (Mugabi & Kisakye 2021).

In Kampala, bananas are consumed in large quantities and have high social and cultural values; however, previous studies have not examined the characteristics of the city's dietary habits and the living environment when discussing the alternative of biomass briquettes. Specifically, extant studies lack perspectives on how much waste material, which can be used as briquette material, is generated from the kitchens of urban households where bananas are consumed, how briquettes are produced by local residents, and changes in the number of producers over the years. The purpose of this study was to examine briquette production in Uganda using urban kitchen waste, such as banana peels, and to assess its applicability in a culture where bananas are a staple food.

This study was conducted intermittently over a total of 20 months spanning from 2012 to 2017. This study conducted semi-structured interviews and participant observation of the production process with individuals, organizations and companies producing biomass briquettes in the Kampala metropolitan area. There are many biomass briquette producers in Uganda, including people from various backgrounds. A wide range of producers were surveyed in this study who were not uniform in terms of place of residence, place of origin, income level, and other factors. Total 16 participants were selected based on availability and access. Briquettes are produced by individuals or community-based organizations (CBOs),[4] non-governmental organizations (NGOs), and companies. The 16 briquette producers surveyed in this study included three individuals who produced briquettes at home, two NGOs, one CBO, nine companies, and one environmental conservation group based at a secondary school. The EEP (2012) classifies the size of production into three categories, namely: the large-scale producers (over 10 tons per month), the medium-scale producers (1 to 10 tons per month), and the small-scale producers (less than 1 ton per month). Among the 16 producers in this study, Company D, G, and J are large scale producers, and Company L is a medium-scale producer. The rest of the 12 producers are small-scale producers. Producers not only make use of the briquettes at their homes but also sell them to generate income.

In addition to the interviews and observations made with regards to the producers, the amount and composition of household waste produced by a certain household over the course of 10 days in Kampala was measured in order to assess the supply of materials for biomass briquetting. This is examined in the section III of the chapter 3 (Briquette production and materials).

Survey Outline

I. Research area

The Republic of Uganda is located in the interior of East Africa. It is surrounded by lush green forests and has a warm and humid climate. Although it is located just below the equator, most of the country is at a high altitude (900–1,500 m), and the temperatures hover between 16–30 degrees Celsius. Kampala receives heavy rainfall from March to May and light rains from October to December, with the average annual rainfall being 1,180 mm (UBOS 2021).

Luganda (language of the Baganda) is used on a daily basis in Kampala, along with English, the official language. The culture of Kampala, including its language, is heavily influenced by the Baganda, the main ethnic group. Bananas form an integral part of the diet and food culture of the Baganda. They are often grown in gardens and vacant lots, even in a crowded city like Kampala. They are a staple food item that is eaten throughout the year, as they can be harvested across the year with some seasonal variations. Furthermore, not only the fruit but also the leaves, leaf axils, and fiber are used for cooking and transportation (Sato 2011).

The diet in Kampala includes many varieties of staple foods apart from bananas. Rice and posho (stiff maize flour porridge) are eaten daily. Other staple foods include sweet potatoes, cassava, Irish potatoes, yams, and pumpkins. The main side dish is a sauce (called *enva* in Luganda), made with a protein source, such as beef, chicken, fish, or beans, cooked in a tomato- or groundnut-based broth. One sauce per meal is enough, but more than two staples are often prepared per meal.

Between 1969 and 2014, the population of Kampala increased by 4.6 times, from 330,000 to 1.52 million (UBOS 2016). According to the recent census, Kampala has a high population density of 9,201 persons per sq. km (UBOS 2016). Compared to the 3.7-fold increase in the overall population of Uganda within the same period, the city of Kampala is experiencing faster population growth and overcrowding.

II. Cooking fuels and briquettes

Woodfuels, such as firewood and charcoal, account for the majority of cooking fuel used in Uganda. In the 2019–2020 fiscal year, the main household cooking fuels were firewood (72.8%) and charcoal (21.4%). In rural areas, firewood was the most commonly used fuel (87.6%), while charcoal was used by 9.2% of the households. In contrast, urban areas predominantly used charcoal (57.0% of households), while firewood was the main cooking fuel in only 29.4% of households. In Kampala, 75.7% of households used charcoal as their main fuel, while only 1.9% used firewood (UBOS 2021). Uganda saw economic growth in the 2005–2016 period, with annual GDP growth averaging 6.5% (World Bank 2016). Kampala became more urbanized and densely populated during this period. However, the number of households using charcoal as the main cooking fuel in

Kampala has not undergone significant change with 75.7% in the 2019–2020 fiscal year compared to 77.7% in the 2005–2006 fiscal year (UBOS 2006, 2021). Despite economic growth and urbanization, charcoal remains the dominant cooking fuel in Kampala.

The availability of firewood is limited in Kampala, and it is mainly used in restaurants and schools, and for events such as weddings and funerals which require a large amount of cooking. Kerosene, LPG, and electricity are sometimes used as heat sources for cooking in Kampala; however, their use is limited to boiling water for drinking and reheating meals, and they are not commonly used for cooking daily meals (Asada 2019).

The price of charcoal has been on the rise in recent years. It saw an increase of 1.8 times in 2011 compared to the previous year (UBOS 2012). In 2017, it was reported to have risen further to 1.3 times the price of the previous year (Musoke 2017). This was partly due to poor weather conditions and high global oil prices as well as the shifting away of the majority of charcoal production from the outskirts of Kampala. Previously, charcoal consumed in Kampala was produced in the nearby area such as Luwero District and Nakasongola District; however, in recent years, charcoal production has expanded to the Northern Uganda and West Nile regions, and sourcing from these regions has increased transportation costs (Tenywa 2011). Reports in 2021 noted that the price of charcoal had increased threefold in the last decade (Tenywa 2021).

As mentioned earlier, briquettes are expected to reduce the consumption of woodfuels. Briquettes are compacted solid fuels made from coal dust, charcoal dust, and biomass residues that can be used for heating and cooking (EEP 2012). Briquettes are expected to be an alternative to woodfuels (Eriksson & Prior 1990). Briquettes made from biomass residues are commonly referred to as biomass briquettes, distinguishing them from briquettes made from fossil fuels, such as coal dust (the briquettes described below refer to biomass briquettes). Biomass residues used for making briquettes include agricultural waste, such as rice husks and maize residues, forestry residues, such as sawdust and offcuts, and organic waste from kitchens. According to previous reports, briquettes are predominantly made from agricultural waste and forestry residues in regions with active agriculture and forestry (Eriksson & Prior 1990; EEP 2012). Production of biomass briquettes started in East Africa and other parts of Africa in the 2000s. Among East African countries, Uganda is the largest producer of biomass briquettes (Ferguson 2012). "Briquette" is the English name majorly used by people in Kampala (spelled out *buliketi* in Luganda), but it is also called "*amanda*" (meaning charcoal in Luganda), "*amanda 'mazungu*" (meaning imported charcoal), or "*amanda agawangala*" (meaning improved charcoal).

Briquettes that undergo a carbonization process during the production are called carbonized briquette, while those that condense the material without carbonization are called uncarbonized briquette. Carbonized briquette burns gradually from the surface to the center, similar to charcoal and coal, and continues to burn for a long time, while uncarbonized briquette burns with a flame similar to burning wood. Carbonized briquettes are used as a substitute for charcoal, while uncarbonized briquettes are used in place of firewood. Carbonized briquettes are

Table 1 Participant characteristics (as of 2017)

Producer	Management Type	Production Scale [a]	Production Start Year [b]	Product Type	Materials	Shape	Presser type	Production method acquired
Mr. MS	Individual	Small	2005	Carbonized briquettes	*Bikuta*	Cylinder	Manual presser	Applied method to produce uncarbonized briquettes made of coffee husks in Eastern Uganda, later developed by Organization X
Ms. DM	Individual	Small	2007	Carbonized briquettes	*Bikuta, lusenyente*	Sphere	Hand-made only	From Mr. MS, developed by Organization X
Mr. SA	Individual	Small	2008	Carbonized briquettes	*Bikuta, lusenyente*	Fan-shaped	Manual presser	Waste management project by a NGO and KCCA, lecture by Organization X
Organization A	CBO	Small	2015	Carbonized briquettes	*Bikuta, lusenyente*	Sphere	Hand-made only	From Company F
Organization B	NGO	Small	2001	Carbonized briquettes	*Bikuta*	Cylinder, honeycomb	Manual presser	Found on the internet
Organization C	NGO	Small	2007	Carbonized briquettes	*Bikuta, lusenyente*	Cylinder, honeycomb	Manual presser	Found on the internet
Company D	Business	Large	1992	Uncarbonized briquettes	Sawdust, agricultural waste	Cylinder	Automobile presser	Research by Makerere University, international consulting company and the Government of India
Company E	Business	Small	2007	Carbonized briquettes	*Bikuta, lusenyente*	Cylinder	Manual and automobile presser	From the internet, Organization X, and another international foundation
Company F	Business	Small	2010	Carbonized briquettes	*Bikuta, lusenyente*	Sphere, honeycomb	Manual presser	By themselves (imitating old solid fuel). Developed by Organization X, ILO
Company G	Business	Large	2011	Carbonized briquettes	*Bikuta,* agricultural waste	Cylinder, honeycomb	Manual and automobile presser	Introduced by a French entrepreneur

Table 1 (Continued)

Producer	Management Type	Production Scale [a]	Production Start Year [b]	Product Type	Materials	Shape	Presser type	Production method acquired
Company H	Business	Small	2011	Carbonized briquettes	*Bikuta, lusenyente*	Cylinder, honeycomb	Manual and automobile presser	From friends, another individual producer, Organization X
Company I	Business	Small	2012	Carbonized briquettes	*Bikuta, lusenyente*	Cylinder, honeycomb	Automobile presser	Lecture by Organization X
Company J	Business	Large	2012	Carbonized briquettes	*Lusenyente*	Pillow-shape	Automobile presser	From themselves (imitated BBQ briquettes in the US)
Company K	Business	Small	2012 [c]	Carbonized and uncarbonized briquettes	Sawdust, waste paper, biochar [d]	Disk (uncarbonized), Sphere (carbonized)	Manual presser	By themselves
Company L	Business	Medium	2013	Carbonized briquettes	*Bikuta, lusenyente*	Honeycomb	Automobile presser	From Organization X (the president used to be a staff of Organization X)
Secondary School M	School	Small	2008	Carbonized briquettes	*Bikuta*, waste paper, *lusenyente*	Sphere, disk	Manual presser	Speech at an Interact Club

a The production of briquettes per month is as follows: large-scale producers produce over 10 tons, medium-scale producers 1 to 10 tons, and small-scale producers produce less than 1 ton.
b The year of production does not always correspond to the year in which the company or organization was established. For example, individuals first start production and later establish companies (such as company F and I which are described in Case Studies 1 and 2); the secondary school M started the production of briquettes as an organization in 2018.
c Company K has been producing carbonized briquettes since 2014.
d Improved cookstoves made by Company K pyrolyze and carbonise biomass inside the pot. For briquettes, they utilize biochar produced during pyrolyzation in their cookstoves.

Source: Compiled by the author based on field surveys.

condensed using a sticky binder and uncarbonized briquette may be bound or thermally compressed (EEP 2012; Mwampamba *et al.* 2013). Predominantly, carbonized briquettes are produced in Uganda. Of the 16 producers interviewed in this study, 15 individuals and companies (94%) produced carbonized briquette as an alternative to charcoal (Table 1).

Carbonized briquettes are burned in the same way as charcoal on a mobile cookstove[5] and used for cooking; however, they differ from charcoal in several ways. Carbonized briquettes collapse when extinguished with water and cannot be reused, are more difficult to ignite than charcoal, must be placed on the stove with good ventilation, and must be stored properly to avoid absorbing moisture. While some people use only carbonized briquettes for cooking, they can also be mixed with charcoal.

The materials used for producing briquettes in Kampala include peels of bananas, cassava, sweet potatoes, and other root crops, charcoal dust (also called *lusenyente* in Luganda), banana leaves, and stems used for cooking. Peels are known as *bikuta* in Luganda and are discharged during cooking in homes and restaurants. In this paper, *bikuta* refers to the peels produced in the kitchen that is used to make briquettes. There is a tendency to avoid using the peels of fruits such as mangoes and jackfruit which have high water content and are difficult to dry. In addition, as a rule, leftover cooked food is not used, as it tends to decompose during drying.

Briquette Production and Materials

I. Producers and start of production

Table 1 shows the 16 participants of this study. It demonstrates their management style, production scale, the year that production began, the kind of briquettes that were produced (carbonized or uncarbonized), the materials used, the shape of the briquettes, the type of presser (pressed by hand, using a manual presser or an automobile presser), and how the method of briquette production was acquired. Carbonized briquettes are largely produced in Kampala, 14 informants produce carbonized briquettes only, one produces uncarbonized briquettes only, and one produces both. *Bikuta* (peels) is a common material for carbonized briquette producers, as it is used by 13 producers. *Lusenyente* (charcoal dust) is another common material. It is used because of its availability, unnecessity of carbonization, and the enhancement in the density of the briquette. Organization C does not use *lusenyente* to avoid using forest resources. Mr. MS, an individual producer, claims that in order to maintain the same level of quality, he solely utilizes *bikuta* for briquettes for sale. According to Mr. MS, *lusenyente* influences the burning quality of briquettes because the quality of the charcoal itself and its dust is not stable. Also, Company J, on the other hand, only uses *lusenyente* in order to skip the labor-intensive carbonization process.

The main form of briquettes can be in sphere, cylinder, and honeycomb shapes (Figure 1). The hand-molded briquettes are in the shape of spheres, whereas the

Figure 1 Carbonized briquettes in a mobile clay stove.
The hand-formed briquette (left) is a sphere with a 5–8 cm diameter. They go into a portable clay stove. The briquettes are broken before being poured into the stove, depending on the size of the stove. A honeycomb briquette (right) is poured in an upgraded cookstove.
Source: (Left) Taken by the author on August 10, 2015. (Right) Taken by the author on October 31, 2017.

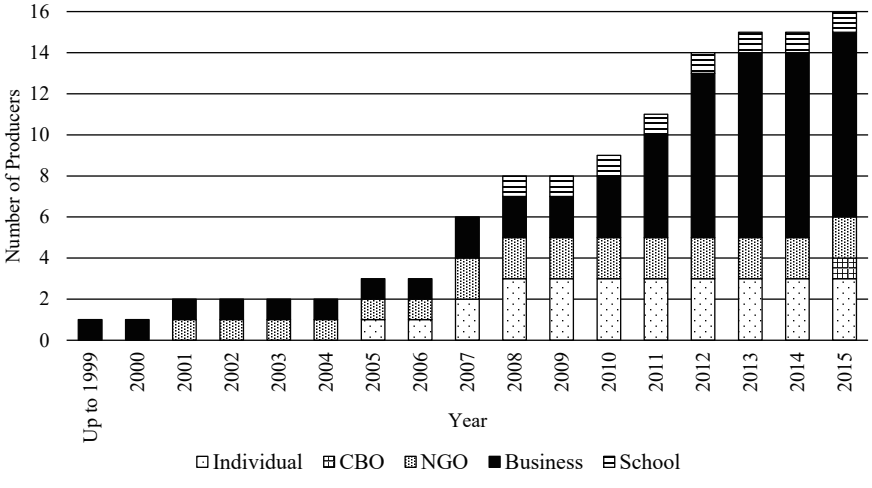

Figure 2 Number of briquette producers and management types.
Source: Compiled by the author based on interviews in the field.

machine-compressed briquettes are in the shape of cylinders, pillows or disks. Honeycomb-shaped briquettes are big cylinders with plenty of holes. They come with an upgraded stove that has a steel cover and a clay inner pot.

The number of individuals and firms embarking on briquette production has increased recently. Figure 2 shows the number of producers by year when briquette production was started. Only Company D started briquette production in the 1990s, and only Organization B started briquette production in the early 2000s, while the other producers started briquette production in or after the latter half of the

2000s. Many producers started briquetting after 2007 which aligns with increased aid from government agencies and international organizations.

The interviews indicated that three sources of information led producers to start briquette production: information outside Uganda, information within Uganda, and the development of their own production techniques.

Information obtained from outside of Uganda involved producers being taught how to produce briquettes by international organizations or learning production methods through the Internet. A senior official of Organization B, an NGO that has been producing briquettes since 2001, discovered that Nepalis demonstrated how to make briquettes on the Internet and began to imitate them.

The sources of information in Uganda included television, radio, friends, and other briquette producers. Company F held workshops on briquette making whenever requested, charging individuals 50,000 Uganda Shillings (USh)[6] to attend a three-day workshop. Mr. PC of Organization A attended the briquette making workshop conducted by Company F.

Those who had developed their own briquette production techniques (Companies F and J) imitated similar solid fuel materials. One of the older producers described how her parents used to crush and roll up dried banana peels to make material for charcoal and heat chicken coops when she was a child. Ms. MJ from Company F recalled her grandparents making solid fuel from dried banana peels when she was a child. The solid fuel that her grandparents made was called *obwanda* in Luganda. It was produced from dried and crushed banana *bikuta*, ash, and ant hill soil. She began to create briquettes out of the *bikuta* that was released from the homes of her neighbors and herself, emulating *obwanda*.

Kampala has hosted an annual exhibition of energy-related products since 2012, organized by the Ministry of Energy and Mineral Development. According to an employee of Company L, an exhibitor in September 2015, their organization was the only one exhibiting and selling briquettes till 2013; however, the number increased to seven organizations in 2015 (interviewed on September 14, 2015). This indicates that the number of briquette producers in Kampala is on the rise.

II. Production method

The common briquette production process consists of five steps: (1) drying the *bikuta* under sunlight, (2) carbonizing the dried *bikuta* by incomplete combustion, (3) crushing the carbonized *bikuta* into small particles and mixing it with the binder, (4) molding the mixture of materials by hand or with a pressing machine (briquetting), and (5) drying the formed briquette in the sun. The binder is made from cassava flour or clay dissolved in water. Some people use a binder made from only one type of material, while others use a mixture of two or more materials. It takes one to three weeks (with some seasonal variations) to complete the production of briquettes (from the drying of the *bikuta* to the drying of the molded briquettes). The materials, the type of binder, and the method of carbonization vary from producer to producer, with each developing their own unique recipes for briquettes through repeated testing and improvement based on the above method.

The production process of Organization A demonstrated the quantity of *bikuta* required to produce 1 kg of briquette. Over a period of 25 days, from January 16 to February 9, 2016, the author observed the briquette production process used by Mr. PC in his 30s and his wife, Ms. SS in her 30s, who were the main briquette producers in Organization A and weighed the materials used at each production stage. Mr. PC and Ms. SS have been producing briquettes on a trial basis at their home site since January 2015 and started their activities as Organization A in February, of the same year.

Mr. PC and Ms. SS started by drying two sacks[7] of *bikuta* on the first day, January 16 (Figure 3-1). The total weight of the two bags of *bikuta* before drying was 117.0 kg. One bag of *bikuta* (55.0 kg) included of 38.3 kg (69.7%) of banana peels, 15.3 kg (27.9%) of Irish potato peels, 1.2 kg (2.2%) of cassava peels, and 0.2 kg (0.3%) of other materials, such as cabbage leaves and onion peels. These bags of *bikuta* were spread out in the garden to dry. It took 14 days for the *bikuta* to dry due to the heavy rainfall during the observation period. The total weight of dried *bikuta* was 19.9 kg.

On the 15th day (January 30), Mr. PC carbonized the dried *bikuta*. He covered the mound of material with wet paper and lit a fire at the center of the mound to prevent the material from turning to ash while carbonizing the *bikuta* (Figure

1 Drying the *bikuta*

2 Carbonizing *bikuta*

3 Mixing the ingredients and molding briquettes

4 Drying

Figure 3 Process of briquette production in Organization A.

3-2). During this process, a small amount of white smoke was generated with no smell. It took one hour to carbonize all the *bikuta*. The carbonized material was transferred to a drum with the fire still burning. A small amount of water was poured on it, and the drum was covered with a lid to extinguish the fire. The weight of the carbonized *bikuta* was 13.5 kg.

On the 17th and 18th days, Ms. SS and her neighbors mixed the carbonized material with *lusenyente* and binders and molded the mixture by hand (Figure 3-3). A total of 24.0 kg of *lusenyente*, 2.4 kg of cassava flour and about 1 kg of clay as binders, were used in the two days to produce a total of 735 hand-rolled briquettes. The molded briquettes were sun-dried on a drying table and a sheet of tin, and they required seven to eight days to dry sufficiently (Figure 3-4). Of the 735 briquettes formed, nine briquettes collapsed and could not be sold, while 726 briquettes were completed. The total weight of the finished products was 32.9 kg, and the volume was less than one sack. In the end, 33 kg of briquettes were produced from 117 kg of *bikuta* and 24 kg of *lusenyente*. For each kilogram of briquettes, 3.6 kg of *bikuta* and 0.7 kg of *lusenyente* were used as raw materials.

While Organization A, led by Mr. PC and Ms. SS, produced briquettes by hand on a small scale, large-scale briquette production processes by companies and NGOs use carbonizers (carbonization drums) to reduce the rate at which *bikuta* turns to ash and increase carbonization efficiency and a pressing machine to prevent the finished product from collapsing. These companies and NGOs could introduce equipment as they expand their production scale to improve production efficiency, reduce material losses, and reduce the amount of *bikuta* required to produce 1 kg of briquette.

III. Materials for briquettes discharged from households

To determine the specific amount of briquette materials generated by households and their share in the total waste, a household in Kampala was surveyed to measure the amount of waste generated over a 10-day period from August 22 to 31, 2016. Three adult women and one child from the household participated in the study. The waste was categorized into eight: organic waste, plastic, waste paper, metal, glass and ceramic, cloth, ash, and miscellaneous, such as dust. The organic waste was divided into *bikuta*, such as banana and root crop peels, which is used to make briquettes, and other residues, such as leftover food and animal organic waste, including meat and fish bones. To determine the relationship between the weight of the waste and the diet, the meals[8] prepared in the household during the study period were recorded.

The surveyed household generated a total of 23.27 kg of waste in 10 days, of which 19.90 kg (86%) was organic waste (Table 2). Among the organic waste, *bikuta* accounted for 14.96 kg (64%). The next item present in large amounts was ash produced during cooking (2.31 kg). The amount of plastic, which is considered to be increasing in recent years, was 0.17 kg (7%). No glass or ceramic was discarded during the ten days of observation. The weight of waste produced per day varied in the quantity of *bikuta*. On August 28th, 29th, and 30th, when

Table 2 Breakdown of meals and waste produced (in kg) in one household in Kampala (10 days: August 22–31, 2016)

Date		Cooked food		Organic waste		Plastic	Paper	Metal	Glass, ceramics	Cloth	Ash	Misc. [c]	Total
		Staple food	Side dish	*Bikuta* [a]	Other [b]								
Aug-23	Mon.	Posho [d]	Bean sauce	0.07	0.69	0.06	0.06	0.00	0.00	0.01	0.13	0.00	1.02
Aug-23	Tue.	Rice	Stir fried cabbage	1.78	0.45	0.02	0.03	0.00	0.00	0.01	0.33	0.05	2.67
Aug-23	Wed.	Posho [d]	Bean sauce	0.39	0.44	0.00	0.00	0.00	0.00	0.00	0.32	0.01	1.16
Aug-23	Thu.	Rice, *matooke*	Nile parch sauce, stir fried cabbage	1.26	0.4	0.01	0.01	0.01	0.00	0.01	0.19	0.00	1.89
Aug-23	Fri.	Posho [d]	Groundnut sauce, Nile parch sauce	0.47	0.22	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.86
Aug-23	Sat.	Rice	Bean sauce	0.09	0.62	0.01	0.03	0.00	0.00	0.00	0.21	0.00	0.96
Aug-23	Sun.	*Matooke*, rice	Groundnut sauce	5.45	0.92	0.03	0.02	0.20	0.00	0.00	0.20	0.06	6.88
Aug-23	Mon.	*Matooke*, posho [d]	Nile parch sauce, bean sauce	2.06	0.68	0.02	0.00	0.00	0.00	0.00	0.40	0.17	3.33
Aug-23	Tue.	*Matooke*, rice	Nile parch sauce, bean sauce	2.59	0.14	0.01	0.00	0.00	0.00	0.00	0.18	0.21	3.13
Aug-23	Wed.	*Matooke*, posho [d]	Groundnut sauce	0.80	0.38	0.01	0.00	0.00	0.00	0.00	0.18	0.00	1.37
Total (kg)		—	—	14.96	4.94	0.17	0.15	0.21	0.00	0.03	2.31	0.05	23.27
(%)		—	—	(64.3)	(21.2)	(0.7)	(0.6)	(0.9)	(0.0)	(0.1)	(9.9)	(2.1)	(100.0)
Average (kg/day)		—	—	1.50	0.49	0.02	0.02	0.02	0.00	0.00	0.23	0.05	2.33

a Banana peels, root crop peels, etc., used as briquetting material
b Leftover food, plant seeds, animal bones, etc.
c Dust, etc.
d Stiff maize flour porridge
Source: Compiled by the author based on field survey.

matooke, a staple banana dish, was cooked, the quantity of waste was high: 5.45 kg of *bikuta* was discharged on the 28th, 2.06 kg on the 29th, and 2.59 kg on the 30th. The total amount of waste was 6.88 kg on the 28th, 3.33 kg on the 29th, and 3.13 kg on the 30th. However, on the 26th, when posho was cooked, the total amount of waste was 0.86 kg, while on the 27th, when rice was cooked, the total amount of waste was 0.96 kg. It should be emphasized that banana cooking generates considerable waste in Kampala households.

The edible part of the banana fruit finger is about 50% of the weight (Sato 2012). When *matooke* was being cooked, the weight of the peel of 35–51 bananas was measured, and it was equal to 37–48% of the weight of the fruit fingers (average 42%). In addition to the fruit fingers, banana stems and leaves used for transport and cooking came to the cities from the rural areas, where they were produced. The plant residues derived from these bananas were used to make briquettes.

Briquette producers obtain materials from their neighborhood or purchase them from vendors. Ms. DM collected the materials from her neighborhood for 58 kgs in 7 days (June 2013), according to the record. Company L purchases not only fresh *bikuta* (2,000 USh per sack), but also train their neighbors how to carbonize it, and buy at a higher price (3,000 USh per sack). This facilitates waste separation and the use of briquettes as an alternative to charcoal while saving time and effort during the carbonization process.

Expansion of Briquette Production and Sales

I. Case studies

This section examines the transition among companies and changes in briquette production methods through the cases of Ms. MJ, the president of Company F, and Ms. BY, the president of Company I.

Case 1: Company F – A mother and daughter started a briquette-making home business

Ms. MJ in her 60s, the president of Company F, started briquette production in April 2010. She is a nurse who runs a small clinic near her home. She and her daughter, a university student with a strong interest in environmental issues, developed a method to produce briquette from *bikuta* (peels), which is readily available. Initially, briquette making was a family activity, but it soon became a neighborhood activity with Ms. MJ and her daughter as the main members. The mother and daughter initiative attracted housewives who lived in the area to produce briquettes, and they started teaching their neighbors how to make briquettes.

About three months after briquette production started, Ms. MJ attended the training course provided by Organization X, an international NGO, for three months. In 2010, Organization X worked to promote briquette production

in Uganda and offered a three-month course to briquette producers on how to carbonize the material efficiently. At the end of the training by Organization X, Ms. MJ received a carbonizer and a manual pressing machine to carbonize the material free of charge. She also entered a competition for environmental projects sponsored by the International Labour Organization (ILO) and received a cash prize of US $700, which enabled her to purchase work equipment, such as gloves and goggles. Subsequently, Ms. MJ set up Company F. As of 2014, the company employed two full-time employees, including a production manager, and 10 to 20 housewives who live in the surrounding area, paying them on an hourly basis. In addition to briquette production, the company holds workshops on briquette making upon request. Twenty people attended a session in March 2014 where they completed the programme. At the conclusion of the training, Ms. MJ addressed the audience in an effort to persuade them to start making briquettes in their local communities in order to reduce their use of charcoal and combat climate change.

Ms. MJ initially started making briquettes on a small scale with her daughter, and within a year, she established Company F. The interest she was able to garner from housewives in the neighborhood, training from Organization X, and the prize money from contests encouraged her to start her own business. Next, Company I, located at a distance of 13 km from the center of Kampala, installed machinery and opened a sales outlet in the city center within three years of starting briquette production.

Case 2: Company I – Expanding production through mechanization

Ms. BY in her 30s, a tax accountant, began working from home as a freelancer in 2012 after quitting her employment. She also began manufacturing briquettes from trash with a neighborhood youth group at the same time. Ms. BY took a briquette-production training course sponsored by Organization X in late 2012 or early 2013, which gave her the idea to start creating briquettes from *bikuta*. Ms. BY and other briquette producers she met at the training have been exchanging assistance and information ever since the training event. Ms. BY registered Company I as a private company in 2013. In 2014, Ms. BY registered Company I with a business incubator [(9)] that supports the operation of companies related to renewable energy after being introduced by a colleague she met at Organization X's training session. She then received guidance and support for managing the business. The business incubator provided funding to Company I in 2015 so that it could construct a briquette sales shop close to Kampala's downtown and buy drying stands and an electric pressing machine. Company I was registered as a limited company in the same year. It has been producing 500 kg of briquettes each week with two full-time staff and three hourly laborers. She maintains contact with other producers who participated in a training session provided by Organization X to enhance the production and qual-

ity of briquettes.

In Uganda, technical and financial assistance for briquette producers has become more common since 2006. Companies F and I received technical, financial, and management assistance from Organization X to expand their businesses. Between 2007 and 2013, Organization X received funding from the French government to support producers of carbonized briquette. Individual producers, such as Mr. MS and Ms. DM, and companies, such as E, F, H, I and L, received the necessary machinery for briquette production free of charge. A business incubator specializing in renewable energy, mentioned in Case Study 2, was established in Kampala in 2011, and provided support to companies, such as L and I. With support from this business incubator, Organization B established a briquette production company in a refugee settlement in western Uganda in 2015. Similar support was provided by Kampala Capital City Authority and an international organization between 2006–2010, and by another international environmental NGO between 2008–2013.

These accounts demonstrate that briquette producers had opportunities to continue and expand production and improve their products. In addition, some producers, such as Ms. MJ of Company F, actively shared their production methods with other companies through workshops, while others, such as Mr. PC of Organization A, started new briquette production businesses.

II. Price of briquette

Charcoal remains the most commonly used cooking fuel in Kampala. As of 2016, the price of charcoal in Kampala was 1,000 Ush per small bucket (about 1 kg), and 50,000 to 70,000 Ush per sack.

The selling price of a briquette is about 1,000 Ush per 1 kg, although it varies slightly from producer to producer. For instance, Ms. DM sells 15 briquettes (about 1 kg) for 1,000 Ush. She produces the briquettes from *bikuta* collected free of charge from her neighbors. The only cost for making a briquette is cassava flour as the binder. Observation of the production process indicated that 0.75 kg of cassava flour (equivalent to 1,700 Ush) was used to make one tub of briquettes (about 40 pieces). The gross margin was 636 Ush per kg.

Company F sells briquettes for 800 Ush per kg. As of August 2015, Company F sold approximately 6.5 tons of briquettes per month, with sales of 5.2 million Ush. Company F produced 8.6 tons of briquettes per month and spent 1.8 million Ush on materials, employee wages, and other expenditures over the same period. The company's profits were 3.4 million Ush. The inventory of 2.1 tons of briquettes produced minus the amount sold was equivalent to a selling price of 1.68 million Ush.

Although briquette companies claim that their products burn for a longer time than charcoal, there is currently little variation in the amount needed to cook a meal. Compared to charcoal and briquettes for cooking steamed bananas for a meal (8.5 kg), 1.7 kg of charcoal was consumed on average (N = 4), and 2.0 kg of briquettes were consumed on average (N = 4). The time for heating did not have a significant difference either (Asada 2021). Brenda *et al.* (2017) asserted

that the briquettes consumed less energy than charcoal did when boiling two liters of water and dried beans, and especially when boiling for more than 30 minutes. In terms of the cost and time, the briquettes are able to perform as well as charcoal does.

Discussion

I. Briquette material availability and organic waste recycling

The raw materials required to make briquettes are available throughout the year in Kampala. Briquettes are made from the residues of staple food crops from household kitchens, particularly banana and root crop peels. Bananas are produced more in Uganda than in other African countries and mostly consumed domestically (Fujimoto & Ishikawa 2016). Bananas were the most produced staple crop in Uganda in 2016 at 8,326,000 tons, followed by cassava at 6,983,000 tons, maize at 3,588,000 tons, and sweet potato at 1,485,000 tons (UBOS 2020). Bananas can be harvested throughout the year, although the yield fluctuates depending on the season. They are consumed in Kampala regardless of the season. Banana peels constitute 40– 50% of the fruit finger. Of the 8.3 million tons of banana produced in Uganda in one year, 3.3–4.2 million tons of peels are discarded. It is difficult to produce briquettes from agricultural residues throughout the year, as the availability of agricultural residues, such as rice husks and maize cobs, is limited to the harvest season. However, banana peels are available regardless of the season.

The high cultural and social values of bananas in Kampala drives their consumption and allows for a steady supply of briquette raw material (Sato 2012). *Matooke* is always served at events, and women are considered to be an adult only when they are able to prepare *matooke* well. Not only the flesh but also peels, leaves, and fiber of bananas are used for various purposes (Sato 2011; Watsemwa 2017). Banana and root crop peels are separated to be used as field compost and livestock feed (Ekere *et al.* 2009; Banga 2011). It has also been utilized for fuel, as Ms. MJ noted. Elderly individuals recall that banana peels can be used as a material for fuel. Therefore, it is likely that residents of Kampala do not hesitate to sort and use banana and root crop peels for making briquettes once they became popular.

Organization A used 3.6 kg of *bikuta* (peels) to produce 1 kg of briquettes. A household waste survey in Bwaise II Parish in northern Kampala showed that 6,662 households generated a total of 1,432 kg of organic waste per day (WaterAid in Uganda *et al.* 2011). In this study, 75% of the organic waste generated by a household was *bikuta*, and it can be calculated that 1,077 kg would be useful as briquette raw material, from which 299 kg of briquettes could be made.

II. Expansion of briquette production

In Kampala, the production of briquettes has been increasing year by year. The

increase in production can be attributed to two factors: the increase in the number of producers and the increase in production scale. The number of producers is increasing, as companies, organizations and individuals who produce briquettes are not monopolizing their technology but rather actively communicating it to others. One of the examples can be seen when Organization A obtained the method by training provided by Company F. Briquette producers use the basic recipe learned from other producers and adapt it to their own facilities and the surrounding environmental conditions. In addition, individuals and organizations are starting to produce briquettes from the *bikuta* generated in the kitchen independently after finding information on the Internet and in the media. Producers work to create high-quality briquettes with powerful heat and prolonged combustion. They continue to seek guidance to enhance their process from a variety of sources, including exchanging ideas with other producers.

Small-scale briquette production is based on manual labor using familiar materials, which lowers the bar for entry into briquette production. While uncarbonized briquettes made from agricultural wastes and forestry residues cannot be produced without a thermocompressing machine and the electricity to run the equipment, small-scale briquette production uses *bikuta* from households with manual machines or molding by hand. Briquettes can be made using cassava flour, which can be obtained at a nearby kiosk, as a binder. Although the process requires space to dry in the sun as well as time and labor, the fact that briquettes do not require special equipment and can be made from readily available materials is an advantage that makes it easy to join briquette production.

The increase in the number of briquette producers is attributed to the introduction of machinery by individual producers and the expansion of the workforce by individuals who produce briquettes within households through the formation of CBOs and entrepreneurship. International environmental groups, like Organization X, and Kampala Capital City Authority have provided technical advice and equipment to a large number of briquette producers, which has enabled them to enhance and increase briquette manufacturing. Graduates continue to share production advice to enhance their products at the trainings. Aid from international environmental organizations and governmental agencies was introduced in the late 2000s with the aim of establishing businesses through the production and sale of briquettes. The majority of aid projects are time-limited, lasting no more than five years; however, according to the interviews conducted during the study, new projects are always emerging. The constant flow of projects to stimulate briquette production creates recurring opportunities for producers to expand their businesses.

III. Utilization of organic waste and new options for cooking fuel

Since Kampala's briquettes are formed from *bikuta* that is generated in kitchens, the city is also where cooking fuel is produced and consumed. This is remarkable compared to briquette making initiatives introduced in other regions and periods. Briquettes made from agricultural waste and forestry residues generated in rural areas far from cities were expensive due to transportation costs and did not become popular as a substitute for woodfuel, which was cheaper (Eriksson &

Prior 1990; EEP 2012). In Kampala, briquettes are made from waste materials collected from kitchens, and the availability of these materials throughout the year makes it possible to set a low price for briquettes. At the time of the survey, the price of briquettes was approximately 1,000 USh per kg, which was almost equivalent to the price of charcoal. People living in Kampala use charcoal as their main cooking fuel, which, unlike in rural areas, must be purchased. However, the price of charcoal has been rising since 2011, especially in recent years, and consequently, it is assumed that the demand for briquettes will increase.

In addition, fuel that burns for a long time, which can be used for simmering, is more convenient for people in Kampala to cook their daily meals than fuel that emits strong heat for boiling (Asada 2019). Charcoal is used to cook bananas that need to be steamed for hours. Briquettes can be used on the same stove as an alternative.

The number of briquette producers in Kampala has been increasing since the late 2000s, with the scale of production expanding. The prospective profitability of briquette production makes it attractive for entry and expansion, and it is establishing itself as a circuit for reusing waste materials that people in the low- and middle-income groups are in charge of.

Under the conditions we have described above, Kampala-produced biomass briquette has potential as an alternative to woodfuel supported by banana-diet food culture. This alternative fuel is being produced from organic waste generated in the city. A high proportion of the organic waste normally produced in people's daily lives is used to produce briquettes, therefore it does not require a lot of money and effort. The demand for briquettes as a substitute for charcoal by consumers is increasing due to the high price of charcoal and the fact that it cannot be replaced by modern energy sources according to the local cooking methods. At present, briquettes are produced in limited quantities. However, briquettes could become a new cooking fuel option or partial substitute and help reduce charcoal consumption and reliance on woodfuel.

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Notes

(1) This article is based on my Japanese paper titled "Active use of household garbage as cooking fuel: A case study of biomass briquette production in Kampala, Uganda" published on pp. 41–60 on *Asian and African Area Studies* (Ajia Afurika Chiiki Kenkyu), No. 18-1 (2018).

(2) In Baganda society, both the fresh staple banana as an ingredient and the cooked *matooke amanige* are called *matooke*. In this paper, for the sake of convenience, I refer to the raw

food item as banana and the cooked product as *matooke*.

(3) There are over fifty ethnic groups in Uganda, with the Baganda being the largest, accounting for 16.5% of the national population (UBOS 2016). Likewise, Baganda is the largest group in Kampala.

(4) Community-based organizations are non-profit organizations operating within a community. To establish a CBO in Uganda, an application must be submitted to the county with a constitution, organizational chart, budget proposal, and activity plan. The scope of activities is limited to the area and community in which it is located.

(5) Kampala is also a major producer of improved stoves with better combustion efficiency. Companies that produce and sell both improved stoves and carbonized briquettes recommend using both briquettes and improved stoves.

(6) The exchange rate for the 2015–2016 fiscal year was 3,443 USh per 1 USD.

(7) The bags are approximately 60 cm × 100 cm in size and are used for the distribution of rice, maize flour, sugar, and other products.

(8) In the household studied, food was cooked only at lunch. Breakfast consisted of bread or leftovers from the previous day and tea, while supper is served from the same menu as lunch. It is not uncommon for households in Kampala to cook food only once per day regardless of the income level.

(9) This refers to organizations and companies that provide support to start-ups with the aim of strengthening management and business. The business incubator supporting renewable energy companies in Uganda was established with the support of The Royal Norwegian Society for Development (NORGESVEL).

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