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Adoption of Briquettes of Organic Matter as an Environmentally Friendly Energy Source in Uganda

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Abstract
Demand for inexpensive alternative fuels and briquettes to bridge the gap between cooking, water heating, and heating production processes has been expanding by the day, due to the current fuel crisis and the ever-increasing costs of electricity and wood charcoal in Kampala and its environs. The goal of this study was to determine the different types of biomass briquettes and associated technology that are available in Kampala. Face-to-face interviews and questionnaires were used to collect data on the numerous varieties of biomass briquettes that are commonly used by Kampala families, as well as the raw materials used by briquette producers. Descriptive statistics techniques were employed. According to the statistics, the most often utilized briquettes in Kampala are stick briquettes, honeycomb briquettes, cylindrical, round, and doughnut-shaped briquettes. While the majority of households continue to use expensive and unreliable energy sources such as wood charcoal, gas, and electricity, using briquettes is less expensive and has the potential to reduce deforestation, minimize waste streams, and reduce indoor air pollution, reduce odors, and increase local job creation. Households that use briquettes lamented a lack of available technology, a lack of equipment for making their own, and a shortage of well-trained or skilled people to assist in waste sorting to gather organic matter for briquette production. It was concluded that carbonized round briquettes are preferred because non-carbonized briquettes are extremely scarce and that a number of factors significantly deterred individuals from investing in biomass briquette technology, including government laxity in providing incentives and a failure to create favorable conditions for individuals to invest in biomass briquette energy production and utilization.

1.0 Introduction

Deforestation-induced environmental degradation is a major source of concern in Sub-Saharan Africa (SSA), particularly in natural forests. It is a well-known fact that population growth will always increase energy consumption. Uganda's population has been growing at an alarming rate over the years. It increased from 9.5 million inhabitants in 1969 to 24.2 million inhabitants and between 1991 and 2002, the population increased at an average yearly rate of 3.2 percent with a projection of 34.1 million by mid-2012 and 80 million by 2040 (UBOS, 2012, 2014, Luwa et al, 2020).

Population growth has resulted in an increase in domestic and commercial wood harvesting, as well as increased pressure and demand on forest resources. Clearing forests for firewood, charcoal manufacturing, and other purposes has increased woodland degradation in forest areas; for example, Uganda's forest cover has dropped from more than 11 million hectares in 1890 to less than 4 million hectares in 2005 (UPSR,2005, Akiyode et al., 2017). Uganda's total forest cover in 2005 was 3.6 million hectares, down from 4.9 million hectares in 1990. This represents a decline of 36.0% during 15 years. In 1990, forests covered 20.4 percent of the land area of the country. By 2005, forest cover had declined to 15.0 percent, corresponding to a 15-year loss of 1.3 million hectares (UBOS, 2012, Mawa et al., 2020).

Numerous developing countries generate enormous quantities of agricultural wastes that are inefficiently disposed of, resulting in extensive environmental damage. The primary wastes include rice husks, coffee husks, jute sticks, bagasse, peanut shells, mustard stalks, and cotton stalks. Additionally, sawdust, a byproduct of milling, is plentiful (MEMD, 2007). Apart from logistics, storage, and handling issues, burning loose biomass in conventional grates produces extremely low thermal efficiency and widespread air pollution. Conversion efficiencies as low as 40% are attained, with particle emissions above 3000 mg/Nm^3, Additionally, there must be a substantial volume of unburned carbonaceous ash disposed of. In the case of rice husks, this translates to more than 40% of the feed that is burned. Briquetting the husks could assist in addressing these pollution concerns while also maximizing the utilization of this essential industrial and residential energy source (Kiza, 2006, Kpalo et al., 2020).

Historically, biomass briquetting technology has progressed in two distinct directions. Europe and the United States sought and mastered the reciprocating ram/piston press, whereas Japan independently developed screw press technology. While both processes have their merits and faults, it is generally agreed that screw-pressed solid briquettes beat ram-pressed solid briquettes in terms of storage and combustibility. Both techniques are used globally to briquette sawdust and other locally available agricultural residues. Plain screw extruders are the most common type in East Africa due to their ease of use and ability to be made with locally available tools. Although the value of biomass briquettes as a substitute fuel for wood, coal, and lignite is widely recognized, the numerous failures of briquetting machines in almost all developing countries, including the requirement for electricity, a high price, a complex mechanism, screw wear and tear, and rust, have limited their widespread use.

Briquetting technology has struggled to establish a firm foothold in a large number of developing countries due to technological constraints and a lack of knowledge necessary to adapt the technique to local conditions. Solving the numerous operational challenges inherent in this technology and ensuring the high quality of the raw materials employed are essential components of its commercial viability. As fossil fuel prices and taxes on energy sources continue to rise, finding alternative, clean, and inexpensive energy sources has become a primary issue for household and national economies. Additionally, economic prosperity and life quality, which are significantly correlated with per capita energy consumption in a number of countries, are crucial determinants and indicators of economic advancement (Yu et al., 2008, Ibrahim, Ajide & Omokanmi, 2021). Energy consumption contributes significantly to global climate change, and resource depletion, and also constrains people's standard of living. By the time gasoline reaches rural areas, the final price is rather expensive due to high transportation costs, compelling residents to seek alternative energy sources such as wood, Uganda's primary source of domestic energy (UNDP, 2003, Olena, Tetiana and Iryna, 2020).

Densification of biomass, often referred to as briquetting, has been practiced in a variety of countries for centuries. Briquetting is currently carried out using two basic high-pressure technologies: the ram or piston press and screw extrusion machines. While piston press briquettes are completely solid, screw press briquettes have a concentric hole that increases the surface area of the briquette and so facilitates burning. Additionally, screw press briquettes are consistent in size and have a high resistance to disintegration. These fuels burn quickly and may be used in the majority of applications and boilers in place of coal. Briquettes with a density of 1.2 grams per cubic centimeter can be manufactured using loose biomass with a bulk density of 0.1 to 0.2 grams per centimeter. These are environmentally friendly because they can be burned in an environmentally acceptable manner (UPSR, 2005).

2.0 Materials and Methods

This study was done in the district of Kampala, Uganda's capital city, as illustrated in Figure 1.0, It is located on the shores of Lake Victoria and has a population of about 1.6 million (UBOS, 2012, KCCA, 2019). It covers an area of 189 kilometers square, of which 13 kilometers square are covered by water.

Figure 1.0:Map of Uganda showing the location of Kampala City and its Divisions.

Local communities and specialists or workers from a variety of organizations were targeted, including the Ministry of Energy

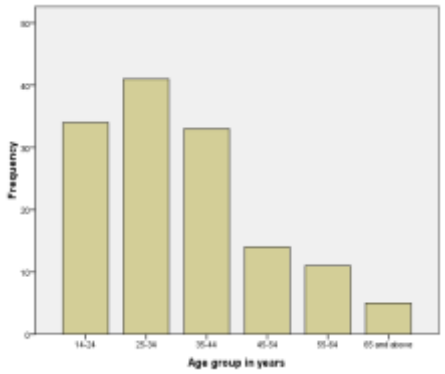
and Mineral Development, a government department responsible for energy-related concerns. Additionally, supporting institutions such as non-governmental organizations (NGOs) and briquette manufacturing enterprises were included in the study. The study included qualitative and quantitative methodologies, including questionnaires and experiments. A study of community members in five villages surrounding Makindye division was conducted regarding the use of briquettes. Additionally, interviews with key informants from briquette manufacturing companies and executives from government energy-related organizations were conducted. Quantitative approaches used in this study included semi-structured questionnaires and laboratory tests. The various divisions initially targeted members of the local population, followed by specialists or officials from the Ministry of Energy and Mineral Development, as well as NGOs and community-based organizations. The proportion of each strata of the population represented in the sample was estimated using stratified random sampling. The target demographics of different members of the local community, experts, and employees were stratified in order to include a representative sample and determine the sample size.

Twenty community members from Kirombe Village, twenty-five from Kiwempe, thirty from Kansanga, forty-eight from Gaba, and fifteen from Bbunga were considered in this case, for a total of 138 respondents. The fieldwork was mostly conducted by open-ended interviews, in-person interactions, and questionnaire administration in households. The interviews were done in conjunction with basic Participatory Appraisal (PA) instruments, which are well-known for their ease of use in swiftly gathering data. The language was simplified to Luganda for those who did not understand English. We investigated the elements that influence people's readiness to accept and use particular types of briquettes, as well as the manufacturing processes, using descriptive statistics, univariate and multivariate techniques, and one-way ANOVA.

3.0 Results

The demographic characteristics of dwellings were analyzed to ascertain their impact on the adoption and use of biomass briquette technology by Kampala's urban population (Figures 2, 3, 4, 5 and 6). The study defined adoption of briquettes as the process through which a household, institution, or organization produces and consumes biomass briquettes energy.

3.1Demographic characteristics of respondents



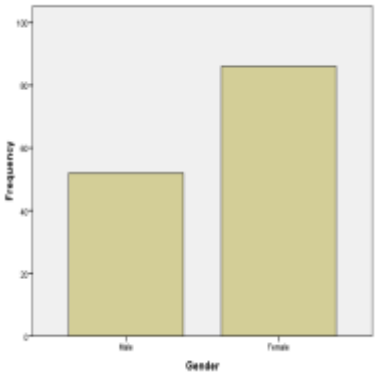


Figure 2, 3&4: Age, gender & marital status of respondents

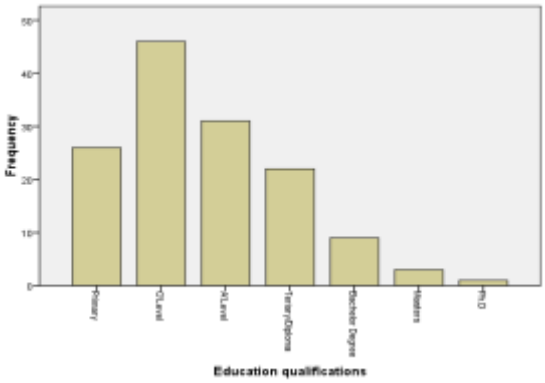
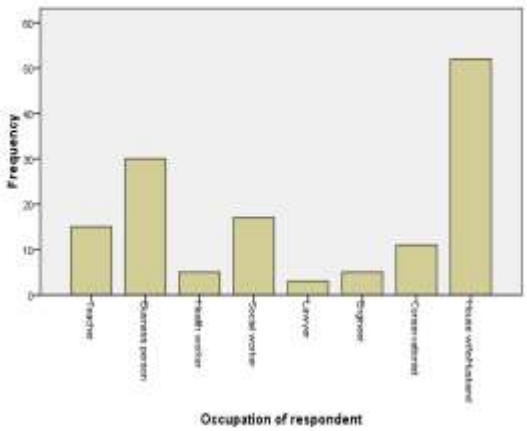


Figure 5&6: Education& occupation of respondents



Numerous elements influence the adoption and consumption of biomass briquettes. As UN-Habitat (2003) reports, in Sub-Saharan African cities, where increasing population, social and cultural adjustments, widespread poverty, insufficient and weak local law enforcement capacity, and limited financial resources all contribute to environmental degradation and waste disposal challenges, the way forward to resolving the energy crisis may be through the deployment of renewable energy technologies such as biomass briquette production and use. Females made up a substantial proportion of respondents in this study (Figure3), owing to the fact that women are disproportionately affected by home energy problems. Women continue to face excessively high costs associated with manual labor and equipment purchase, and women are also better suited to communicate the socioeconomic consequences of wood charcoal use.

Individuals' educational levels were used to ascertain their family's economic status, economic activity, and potential to establish and sustain biomass briquette manufacture and supply. These findings corroborate those of Bekele and Drake (2003), who noted that available research on adoption behavior in a variety of communities correlates with the social, personal, physical, economic, and institutional factors that are critical determinants of biomass briquettes adoption as a renewable energy source.

3.2 Types of biomass briquettes used in Kampala city

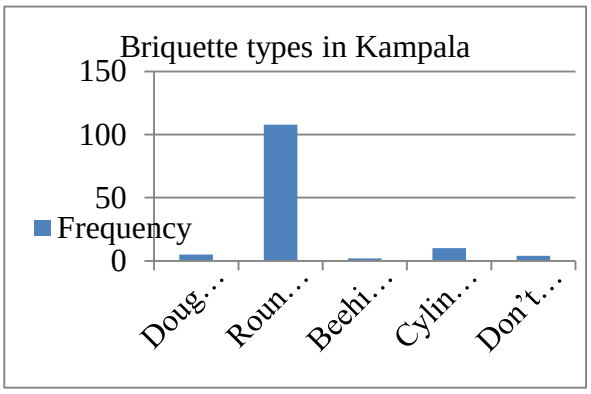


Figure 7: Briquette types used in Kampala.

The demographic characteristics of houses were investigated in order to determine their influence on the adoption and use of biomass briquette technology by Kampala's urban population (Figures 2, 3, 4, 5 and 6). Adoption of briquettes was defined in the study as the process by which a home, institution, or organization generates and consumes energy from biomass briquettes. Numerous factors contribute to the acceptance and consumption of biomass briquettes. As UN-Habitat (2003) noted in Sub-Saharan African cities where population growth, social and cultural adaptations, widespread poverty, insufficient and weak local law enforcement capacity, and limited financial resources all contribute to environmental degradation and waste disposal challenges, the path forward to resolving the energy crisis may be through the deployment of renewable energy technologies such as biomass briquette production and use.

Female respondents comprised a sizable share of this study's respondents (Figure3), owing to the fact that women are disproportionately affected by residential energy difficulties. Women continue to bear disproportionately high expenses related with manual labor and equipment acquisition, and women are also better equipped to articulate the socioeconomic implications of wood charcoal use. The educational levels of individuals were utilized to ascertain their family's economic condition, economic activity, and capacity to create and sustain biomass briquette manufacturing and supply. These findings corroborate Bekele and Drake's (2003) observation that available research on adoption behavior in a variety of communities correlates with the social, personal, physical, economic, and institutional factors that are critical determinants of biomass briquettes adoption as a renewable energy source.

3.3 The factors affecting the adoption of biomass briquettes in Kampala.

The briquette technique was primarily distinguished by its shape, rather than its manufacturing mechanism. From a technological standpoint, one of the most common variables in the biomass briquette manufacturing process that has an effect on adoption is the method used to dry the biomass. Manufacturers may employ torrefaction, carbonization, or varying degrees of pyrolysis, and their findings are consistent with those of Nasrin et al., (2008), who observed the same behavior. While respondents indicated that torrefaction and carbonization are the most efficient methods of drying biomass, respondents indicated that the process used is determined by the purpose of the briquette. Due to the respondents' inability to acquire machinery, briquettes were hand-molded into round shapes at the household level. Compaction is another factor that affects manufacturing, which in turn affects the availability of adoption. Certain materials, such as corn stover grinds, burn more efficiently when compressed under low pressure. When subjected to high pressure, other materials, such as wheat and barley-straw, generate heat.

Respondents stated that they could shape briquettes using only their hands and a moderate amount of water mixed with soil and charcoal particles in their homes. A piston press is used to manufacture solid briquettes for a variety of applications. Screw extrusion is used to compact biomass into uniform, loose briquettes suitable for co-firing with coal. This method results in a briquette that is shaped like a toroid or doughnut. The hole in the center of the briquette increases the surface area, which results in a faster rate of combustion (Ferguson, 2012). On the other hand, commercially produced briquettes were less prevalent than round-shaped briquettes made by families. Additionally, the results indicated that household use of biomass briquettes has been steadily increasing as families recognize the benefits of pollution reduction through biomass briquette use.

Briquettes have a higher calorific value per dollar than wood fuel when used to power industrial boilers. Along with enhanced

calorific value, biomass briquettes reduced boiler fuel costs by an average of 30%–40%. Briquettes, on the other hand, may only drastically cut the usage of wood charcoal in the long run, although they are increasingly being pursued by urban households and businesses in Kampala. Domestic manufacturing of the basic materials results in a fuel source that is not dependant on foreign sources and is less polluting than charcoal and fossil fuels. Environmentally, biomass briquettes result in a significant reduction in greenhouse gas emissions, namely 13.8 to 41.7 percent CO_2 and N_2O. Carbon and other greenhouse gases continue to be released into the atmosphere, causing global temperatures to rise (Ferguson, 2012).

3.4 Socioeconomic implications of briquette technology use and uptake.

Table 2: One-Sample Kolmogorov-Smirnov t-test.

Socio-economic responses for peoples' use and adoption of briquette technology	**T**	**DF**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Gender of respondent	38.2	105	0.00	2.36	2.24	2.48
Marital status	38.2	105	0.00	2.32	2.20	2.44
Education qualification	54.1	105	0.00	3.19	3.08	3.32
Occupation of respondent	50.8	105	0.00	2.19	2.11	2.28
Knowledge about Briquettes	37.4	105	0.00	2.46	2.33	2.59
Common types of Briquettes used	28.0	105	0.00	2.50	2.32	2.68
Do you make your own Briquettes or Buy them?Reasons why Briquettes are your choice than wood charcoal?	31.2	105	0.00	2.08	1.94	2.21
Biogas is a renewable energy option	43.2	105	0.00	3.14	3.00	3.29
Biogas is easy to make	26.2	105	0.00	1.97	1.82	2.12
Biogas cooks better than other fuels	58.7	105	0.00	3.42	3.30	3.53
Biogas cooks faster and saves time	71.9	105	0.00	3.35	3.26	3.44
Size of a Briquette used in cooking food in (cm)	57.9	105	0.00	3.08	2.97	3.18
Where is more money spent? On 1bag of Briquettes or 1bag of Wood charcoal?	38.7	105	0.00	2.12	2.01	2.23
To what extent has Government been involved in promoting the adoption of Briquettes by people?	44.8	105	0.00	2.69	2.58	2.82
Challenges by the Government in promotion of Briquette usage	50.7	105	0.00	2.76	2.66	2.87
Any other energy alternatives apart from Briquettes and Wood charcoal	57.4	105	0.00	3.15	3.04	3.26

Source: Primary data

Socioeconomic considerations have a negligible effect on people's use and adoption of briquette technology," the hypothesis stated. The t-test result indicated that the null hypothesis was rejected with 0.00<t values, p=0.05, two-tailed, df=105. The findings reveal that socioeconomic factors significantly influence the general public's adoption and use of biomass briquette technologies as viable renewable energy sources (Table 2). Social and economic factors influenced respondents' responses to the following issues, which must be addressed further in order to increase the accessibility and adoption of alternative and renewable energy sources as a substitute for hydro-electricity and wood charcoal among the urban population in Kampala district. The investigation sought to ascertain the following:

Can the majority of urban households and individuals engaged in small-scale companies such as poultry afford the initial investment in briquette technology and maintain the expenditures in the Kampala district?

Is it possible for the poor to acquire financial/credit incentives from the Ugandan government to assist them in purchasing briquette production machines?

Is the national government committed to disseminating critical information regarding biomass briquette technology via trainings and public awareness campaigns?

What economic benefits does forest conservation provide to families or businesses that use briquettes instead of wood charcoal?

According to the study represented in Figure 3, the majority of Kampala residents rely on kerosene for lighting and cooking in their homes as the unit cost of hydroelectricity climbs beyond the reach of low-income earners. Kerosene combustion, on the other hand, is not environmentally beneficial, as it emits large amounts of greenhouse gases into the atmosphere.

Gender, marital status, education level, occupation, awareness about briquettes, varieties of briquettes, manufacturer of briquettes, accessible energy options, and briquette price were identified as the key socioeconomic factors impacting briquette use in households in the Kampala urban region. The city's population is increasing, which means that demand for energy and economic activities are increasing as well. These characteristics persist in Kampala, implying that households will continue to use wood charcoal unless all stakeholders prioritize the use and adoption of biomass briquettes (UNDP, 2003).

The respondents recognized that, even if the installation requirements for this cutting-edge energy technology remain prohibitively expensive for many households, biomass briquette technology has the potential to promote good sanitation and hygiene in cooking and lighting, in addition to other societal benefits, including the reduction of organic solid wastes, particularly agricultural wastes, the creation of new jobs, and a two- to three-hour reduction in household workload. Multiple linear regression analysis was used to predict variables' values based on the values of other variables. For example, in order to

forecast the processes involved in the manufacture of briquettes, the raw materials required by briquette makers had to be forecast.

Table 3a: Descriptive statistics

Variables regressed	Mean	Std. Deviation
Occupation of respondent	5.04	2.786
Age group	2.58	1.366
Education qualification	2.67	1.313
Marital status	1.93	1.148
Gender of respondent	1.62	0.486
Knowledge about Briquettes	1.04	0.188
Do you make your own Briquettes or buy them?	1.95	0.517
Reasons why Briquettes are your choice over wood charcoal?	2.35	1.488
To what extent has Government been involved in promoting the adoption of Briquettes by people?	3.40	1.008
Efforts by Government to promote Briquette use	2.65	0.843
Any other energy alternatives apart from Briquettes and Wood charcoal	2.14	1.147

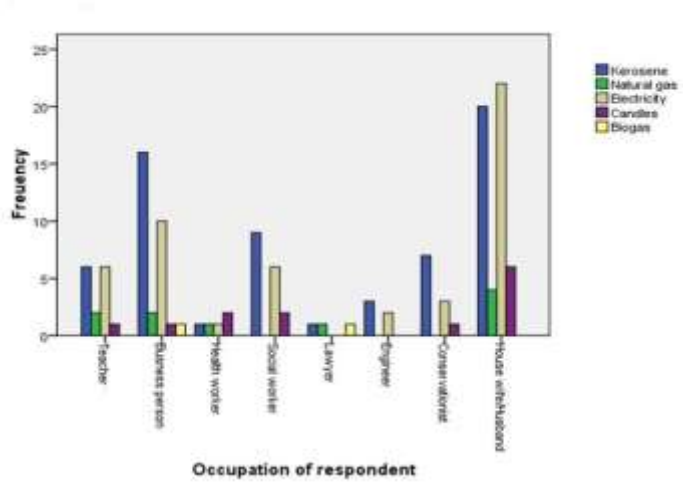


Figure 8: Most commonly used alternative fuel sources other than briquettes in Kampala by classes of individuals.

In an interview with one respondent who previously manufactured briquettes for domestic use and surplus for sale, the following was stated about the briquette manufacturing process: "I obtain wood charcoal dust and sieve to obtain the finer dust, then add cassava porridge to the finer charcoal dust, add some clay, stir and thoroughly mix everything, and then mould the briquettes with a machine into desired shapes, usually round or stick shapes."

Njenga et al. (2009).advised conducting similar investigations into the materials used to manufacture briquettes, dubbed "Binding" The linear regression analysis was performed to determine the effect of several factors on people's desire to manufacture or use briquettes as a sustainable energy source in place of wood charcoal, fossil fuels, or even electricity (Table 3a, b & c). This technique best displayed how market demand and awareness of the use and efficacy of briquettes as a substitute for wood charcoal might affect briquette production statistics.

The big standard deviation of 2.786 and the tiny standard deviation of 0.188 (Table (3a) show that the means are not widely dispersed around the arithmetic mean and hence that the data distribution is normal, the R square values for predictors a=0.016 (education level and age of individuals have a 1.6 percent effect on occupation and type of fuel used, whereas other factors have a 98.4 percent effect on briquettes or wood charcoal usage) (Table 3b). Only R = 0.022 indicates the extent to which occupation, education, sex, and marital status affect knowledge about the use and fabrication of biomass briquettes (2.2 percent). Other variables explain 97.8% of the variation in people's use and acceptance of biomass briquettes over wood charcoal (Table 3b). Education and occupation have a 5.3 percent effect on people's use and acceptance of briquette technology; the government's commitment to promoting the use of biomass briquettes as a renewable energy source in place of wood charcoal has a 5.4 percent effect; and other alternative fuels such as fossil fuels have a 5.8 percent effect.

According to Table 3c, the values of the statistical test Analysis of Variance (one way-ANOVA) at p=0.05, one-tailed for predictors a= 0.342^{a}, b= 0.554^{b}, c= 0.620^{c}, d= 0.403^{d}, e=, 0.639^{e}, and f=0.612^{f}, suggest that one component (s) has a moderate to significant positive influence on the others. This means that residents of Kampala's use and acceptance of briquette technology to protect degraded tropical forests from further damage caused by increased demand for wood charcoal is influenced by a variety of factors that necessitate a comprehensive approach from both the government and the international community.

Table 3 b: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.126[a]	0.016	0.001	2.785	0.016	1.082	2	135	0.342
2	0.149[b]	0.022	-0.007	2.796	0.007	0.443	2	133	0.643
3	0.161[c]	0.026	-0.011	2.802	0.004	0.510	1	132	0.476
4	0.231[d]	0.053	0.002	2.783	0.027	1.868	2	130	0.159
5	0.231[e]	0.054	-0.013	2.804	0.000	0.021	2	128	0.979
6	0.242[f]	0.058	-0.016	2.808	0.005	0.661	1	127	0.418

a. Predictors: (Constant), Education qualification, Age group

b. Predictors: (Constant), Education qualification, Age group, Gender of respondent, Marital status

c. Predictors: (Constant), Knowledge about Briquettes

d. Predictors: (Constant), Do you make your own Briquettes or Buy them? Reasons why Briquettes are your choice other than wood charcoal?

e. Predictors: (Constant), Efforts by Government to promote Briquette use, To what extent has Government been involved in promoting the adoption of Briquettes by people?

f. Predictors: (Constant), Any other energy alternatives apart from Briquettes and Wood charcoal

4.0 Conclusions

The investigation concluded as follows: Round carbonized briquettes are the most prevalent type of briquette in Kampala (much more than the other types, as illustrated in Figure 7), accounting for the bulk of those hand-molded at the household level. Cylindrical briquettes are the most common because they fit into small, less expensive stoves, whereas doughnut and beehive briquettes are less popular because they were intended for commercial usage, a sector that has yet to embrace briquette technology. Numerous elements influencing household adoption and acceptance of biomass briquette technology have been identified. These features included education level, which may impact the decision to invest in briquette technology, socioeconomic and institutional considerations, such as income levels, and national government incentives delivered through individual families.

The government's inability to provide incentives, the absence of a tax holiday on machine imports, and the absence of a favorable atmosphere for private investment in biomass briquette energy production and consumption all contributed to the briquette industry's collapse. It is projected that demand for charcoal from forests would continue to expand as the population grows, without regard for the aforementioned issues,

5.0 Recommendation

While the study recommended that efforts be made to maximize the amount of energy released by a briquette via improved technology, it also recommended that an emphasis be placed on making simple machines suitable for household use available to encourage those already producing briquettes to expand production by utilizing locally available raw materials. When designing projects in the renewable energy sector, all stakeholders should take into account the elements determining briquette adoption.

Declaration of conflict of interest

None

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