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Performance of Biomass Briquettes as an Alternative Energy Source Compared to Wood Charcoal in Uganda

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***Abstract*—** *The environmental, financial and social questions, as well as the rapid increase in demand for energy fuels, emphasize the need to investigate and generate information on the performance of charcoal compared to briquettes as an alternative source of renewables in Kampala district. The study objective was to compare the performance of biomass briquettes as an alternative energy source to wood charcoal. The performance was measured using a modified water boiling test and a controlled cooking test. Data collected were analyzed using chi-square tests and cross tabulations on households' socio-economic factors that promoted the popularity and use of briquettes or wood charcoal. Results from the modified water boiling test showed that the weight of wood charcoal, carbonized and non-carbonized briquettes consumed in boiling two litres of water is significantly different. From the controlled cooking test, the weight of charcoal used to cook dry beans is significantly higher than that of briquettes used to cook the same amount of beans. It was recommended that wood charcoal and briquettes perform similarly when used over short periods of time, but briquettes perform better over much longer periods.*

***Keywords*—** *Biomass Briquettes, Wood charcoal, Carbonized and non-carbonized briquettes.*

I. INTRODUCTION

Energy from biomass accounts for about 15% of the global energy consumption, yet in Uganda, it supplies more than 90% of the country's energy needs. Biomass for energy consists of any organic material that can be used as a fuel, including firewood, charcoal, forest wastes, dung, vegetable matter and agricultural residues (Ferguson, 2012). Many types of household fuels used in developing countries come under the category of "traditional," which include animal dung and agricultural residues, as well as wood fuel. Wood fuel, in the view of World Resources (2001), comprises of charcoal, firewood and other wood-derived fuel and also constitutes the most important form of non-fossil energy used in households. In urban areas, a wide selection of household fuels and equipment is available for use. Of all sectors, the household sector experiences the most pronounced changes in its pattern of fuel use over time. Typically, a household may shift from biomass to kerosene, gas. Finally to electricity for specialized cooking. This shift phenomenon is often referred to as 'fuel transition' from traditional (biomass-based) to modern household fuels. Despite a major shift in the household energy types used, many households rely solely on charcoal as their primary source of cooking energy, especially in urban areas (Sathaye & Taylor, 1991). The calorific value of a basic paper/sawdust briquette is around 15 MJ/kg. This value differs, depending on the selection of raw materials. It can be compared to firewood that is around 16 MJ/kg (dependent on moisture content) and charcoal around 30 MJ/kg (CEEDS, 2000). These values of energy gained from a briquette vary with the shapes, sizes, materials as well as stoves used. Therefore, it is still a challenge for engineers and scientists to build efficient biomass briquettes with materials available, at the same time taking the local and economic considerations into account. Although the use of briquettes is on the increase, additional research and awareness are needed to meet the changing needs and conditions. The purpose of this study was to compare the performance of biomass briquettes as an alternative energy source to wood charcoal.

II. MATERIALS AND METHODS

Study Area

This study was carried out in Kampala District which is the capital city of Uganda. It is located on the shores of Lake Victoria with a population of about 1,597,900 people (UBOS, 2012). It covers a total area of 189 km^2, of which 13km^2 is water.

The study used both qualitative and quantitative research designs, including surveys and experimentation. A survey was conducted among community members of 5 villages around Makindye division on the use of briquettes. Interviews with the major informants in organizations involved in briquette manufacturing as well as officials from government organizations involved in the energy sector were also conducted. The quantitative part involved semi-structured questionnaires and experiments.

The target population was the local communities and experts or employees from various organizations such as the Ministry of Energy and Mineral Development, which is a government ministry in charge of energy-related issues. Supporting organizations such as NGOs and briquette manufacturing organizations were also involved in the study.

Fieldwork was conducted mainly through experiments. Ordinary charcoal stoves were weighed with and without charcoal and briquettes before use and weighed again after boiling the water first and then beans in the modified water

boiling test and controlled cooking test. Time taken was also determined. The Chi-square test was used to compare the amount of wood charcoal and briquette fuel taken to boil the same amount of water in the Modified Water Boiling Test (MWBT) and the same amount of beans in the Controlled Cooking Test (CCT).

III. Results and Discussion

Table 1a: Modified water boiling test (MWBT) results.

	Charcoal mixture	Carbonized briquettes			Non-carbonized briquettes		
		BR1	BR2	BR3	BR1	BR2	BR3
Materials Used	3 samples average	Organic matter+ cassava	Charcoal dust+ clay	Charcoal dust+loam soil	Paper	Sawdust	Coffee husks
Time taken	16.5mins	12mins	11mins	13mins	18mins	16mins	16mins
Wt of fuel used /gms	392	180	200	231	280	291	300

Source: Primary data, 2014.

Table 1b: Controlled cooking test (CCT) results

	Charcoal mixture	Carbonized briquettes			Non carbonized briquettes		
		BR1	BR2	BR3	BR1	BR2	BR3
Materials Used	3 samples average	Organic matter+ cassava	Charcoal dust+ clay	Charcoal dust+loam soil	Paper	Saw dust	Coffee husks
Time taken	2hrs, 22mins	3hrs,3 mins	2hrs,58 mins	3hrs, 6mins	3hrs, 9mins	3hrs, 10mins	3hrs, 15mins
Wt of fuel used/gms	1560	460	421	452	556	512	542

Source: Primary data, 2014.

Table 2: Chi-square statistic tests for the Modified Water Boiling Test (MWBT) and Controlled Cooking Test (CCT).

Table 2a: MWBT: Comparing all types (wood charcoal, carbonized and non-carbonized briquettes)			
	Wood charcoal	Carbonized briquettes	Non-carbonized briquettes
Observed weight (g)	392	203.7	290.3
Expected weight (g)	295	295.3	295.3
Test Statistics			
	wood charcoal, carbonized and non-carbonized briquettes		
Chi-Square	0.000[a]		
Df	2		
Asymp. Sig.	60.17		
a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 138.0. Chi-tabulated is 9.21, df=2, 2 tailed test, α=0.01.			

Source: Primary data, 2014.

Table 2b: CCT: Comparing all types (wood charcoal, carbonized and non-carbonized briquettes)			
	Wood charcoal	Carbonized briquettes	Non-carbonized briquettes
Observed weight (g)	1560	444.33	536.67
Expected weight (g)	847	847	847
Test Statistics			
	wood charcoal, carbonized and non-carbonized briquettes		
Chi-Square	0.000[a]		
Df	2		
Asymp. Sig.	905.3		
a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 138.0. Chi-tabulated is 9.21, df=2, 2 tailed test, α=0.01.			

Source: Primary data, 2014.

The null hypothesis was that "the weight in grams of wood charcoal, carbonized and non-carbonized briquettes taken to cook the same amount of water and dry beans is similar". From Table 2a, the null hypothesis is rejected, and the weight of wood charcoal, carbonized briquettes and non-carbonized briquettes consumed in boiling two litres of water is significantly different (χ^2 cal=60.67> χ^2 tab=9.21,p=0.01, 2-tailed, df=2). From Table 2b, the null hypothesis is also rejected therefore the weight of wood charcoal, carbonized and non-carbonized briquettes taken to cook the same amount of dry beans is significantly different (χ^2 cal=905.3> χ^2 tab=9.21,p=0.01, 2-tailed, df=2). This means the three energy types perform differently regarding energy output.

These findings are related to (Olof & Olle, 2006) who asserted that although briquettes ignite more easily than charcoal, they produce quite a lot of ash. Since they are made out of organic matter, especially the non-carbonized ones, for example, the briquettes from CWAG (Chembe Women's Aquaculture Group, Malawi) produced too much smoke to allow somebody to be able to stay close to the stove for tendering. When burned, they produced a big amount of ash, which filled up the stove and clogged the air holes hence may not cook food at the same amount of time.

The null hypothesis is "the weight of wood charcoal and carbonized briquettes taken to boil the same amount of water and dry beans is similar." The results (Table 2c) show that the weight of wood charcoal taken to boil two litres of water is significantly higher than the weight of carbonized briquettes taken to boil the same amount of water, (χ^2cal 59.54> χ^2tab 6.63, df=1, p=0.01, 2-tailed test). From Table 2d the weight of

charcoal taken to cook the dry beans is significantly higher than that of briquettes (χ^2cal 621> χ^2tab 6.63, df=1, p=0.01, 2-tailed test). According to respondents, 1kg of briquettes costs Ugandan shillings (Ushs) 1,200 and 1kg of charcoal costs Ushs 1500. This means that for the MWBT, the charcoal costs Ushs 588 and the briquettes cost Ushs 244 while for the CCT, charcoal costs Ushs 2,340 and briquettes cost Ushs 533. This is because briquettes maintain their heat consistently for longer periods for example whereas charcoal burned out and more had to be added twice in the 2hours and 22mnutes in which the beans were cooked, the same briquettes were used for 3 hours to cook the beans in the CCT (Table 1b).

Table 2c: MWBT: Comparing wood charcoal and carbonized briquettes

	Wood charcoal	Carbonized briquettes
Observed weight (g)	392	203.7
Expected weight (g)	297.84	297.84
Test Statistics		
	wood charcoal and carbonized briquettes	
Chi-Square	0.000[a]	
Df	1	
Asymp. Sig.	59.54	
a. 0 cells (0%) have expected frequencies less than 5. The minimum expected cell frequency is 138.0, χ^2 tab is 6.63, df=1, 2 tailed test, α=0.01.		

Source: Primary data, 2014.

Table 2d: CCT: Comparing wood charcoal and carbonized briquettes

	Wood charcoal	Carbonized briquettes
Observed weight (g)	1560	444.33
Expected weight (g)	1002.17	1002.17
Test Statistics		
	wood charcoal and carbonized briquettes	
Chi-Square	0.000[a]	
Df	1	
Asymp. Sig.	621	
a. 0 cells (0%) have expected frequencies less than 5. The minimum expected cell frequency is 138.0, χ^2 tab is 6.63, df=1, 2 tailed test, α=0.01.		

Source: Primary data, 2014.

Table 2e: MWBT: Comparing wood charcoal and non-carbonized briquettes

	Wood charcoal	Non-Carbonized briquettes
Observed weight (g)	392	290.33
Expected weight (g)	341.17	341.17
Test Statistics		
	wood charcoal and non-carbonized briquettes	
Chi-Square	0.000	
Df	1	
Asymp. Sig.	15.15	
a. 0 cells (0%) have expected frequencies less than 5. The minimum expected cell frequency is 138.0. X^2cal 15.5> X^2tab 6.63, df=1, 2 tailed test, α=0.01.		

Source: Primary data, 2014.

Table 2f: CCT: Comparing wood charcoal and non-carbonized briquettes

	Wood charcoal	Non-Carbonized briquettes
Observed weight (g)	1560	536.67
Expected weight (g)	1048.335	1048.335
	wood charcoal and non-carbonized briquettes	
Chi-Square	0.000	
Df	1	
Asymp. Sig.	499.46	
a. 0 cells (0%) have expected frequencies less than 5. The minimum expected cell frequency is 138.0. X^2cal 499.46> X^2tab 6.63, df=1, 2 tailed test, α=0.01.		

Source: Primary data, 2014.

However, households in a bid to save time usually light 2-3stoves to prepare the dishes at once and charcoal being more in volume meets this need better than briquettes. These findings are related to that of (Olof & Olle, 2006) who stated that briquettes ignite more easily than charcoal.

Hypothesis: "the weight of wood charcoal and non-carbonized briquettes taken to boil the same amount of water and dry beans is similar". Results from table 2e show that the weight of wood charcoal taken to boil two litres of water was significantly higher than the weight of non-carbonized briquettes taken to boil the same amount of water (X^2cal 15.15 >χ^2tab 6.63, df=1,p=0.01, 2-tailed). From table 2f, the weight of wood charcoal taken to cook the dry beans is significantly higher than that of briquettes (X^2cal 449.46 >χ^2tab 6.63, df=1, p=0.01, 2-tailed).

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Why briquettes are preferred to Charcoal.

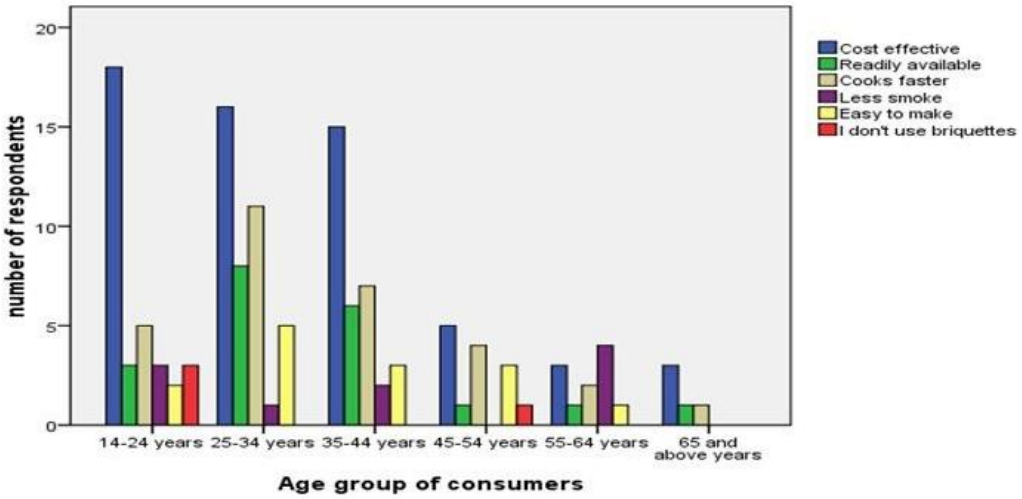

Figure 1: Reasons for consumer preference of briquettes to wood charcoal.

Table 3: Age group * Reasons why Briquettes are chosen over wood charcoal.
(*cross-tabulation-analysis)

Age group (Years)		Reasons why Briquettes are chosen over wood charcoal?						Total
		Cost effective	Readily available	Cooks faster	Less smoke	Easy to make	I don't use briquettes	
14-24	Count	18	3	5	3	2	3	34
	% within Age group	52.9%	8.8%	14.7%	8.8%	5.9%	8.8%	100.0%
	% within Reasons why Briquettes are chosen over wood charcoal?	30.0%	15.0%	16.7%	30.0%	14.3%	75.0%	24.6%
	% of Total	13.0%	2.2%	3.6%	2.2%	1.4%	2.2%	24.6%
25-34	Count	16	8	11	1	5	0	41
	% within Age group	39.0%	19.5%	26.8%	2.4%	12.2%	0.0%	100.0%
	% within Reasons why Briquettes are chosen over wood charcoal?	26.7%	40.0%	36.7%	10.0%	35.7%	0.0%	29.7%
	% of Total	11.6%	5.8%	8.0%	0.7%	3.6%	0.0%	29.7%
35-44	Count	15	6	7	2	3	0.0	33
	% within Age group	45.5%	18.2%	21.2%	6.1%	9.1%	0.0%	100.0%
	% within Reasons why Briquettes are chosen over wood charcoal?	25.0%	30.0%	23.3%	20.0%	21.4%	0.0%	23.9%
	% of Total	10.9%	4.3%	5.1%	1.4%	2.2%	0.0%	23.9%
45-54	Count	5	1	4	0	3	1	14
	% within Age group	35.7%	7.1%	28.6%	0.0%	21.4%	7.1%	100.0%
	% within Reasons why Briquettes are chosen over wood charcoal?	8.3%	5.0%	13.3%	0.0%	21.4%	25.0%	10.1%
	% of Total	3.6%	0.7%	2.9%	0.0%	2.2%	0.7%	10.1%
55-64	Count	3	1	2	4	1	0	11
	% within Age group	27.3%	9.1%	18.2%	36.4%	9.1%	0.0%	100.0%
	% within Reasons why Briquettes are chosen over wood charcoal?	5.0%	5.0%	6.7%	40.0%	7.1%	0.0%	8.0%
	% of Total	2.2%	0.7%	1.4%	2.9%	0.7%	0.0%	8.0%
65 and above	Count	3	1	1	0	0	0	5
	% within Age group	60.0%	20.0%	20.0%	0.0%	0.0%	0.0%	100.0%
	% within Reasons why Briquettes are chosen over wood charcoal?	5.0%	5.0%	3.3%	0.0%	0.0%	0.0%	3.6%
	% of Total	2.2%	0.7%	0.7%	0.0%	0.0%	0.0%	3.6%
Count		60	20	30	10	14	4	138
% within Age group		43.5%	14.5%	21.7%	7.2%	10.1%	2.9%	100.0%
% within Reasons why Briquettes are chosen over wood charcoal?		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
% of Total		43.5%	14.5%	21.7%	7.2%	10.1%	2.9%	100.0%

Source: Primary data, 2014.

The responses were obtained from different individuals using briquettes in their homes or at the level of small and medium industries. Results from the cross tabulation (Table 3) show that 43.5% of the respondents were using briquettes because of their cost effectiveness (briquettes were less costly and lasted much longer before getting used up than wood

charcoal) hence this finding is in tandem with (Ferguson, 2012) who also noted that carbonized briquettes can act as a replacement for charcoal for domestic and institutional cooking and heating, where they are favored for their near-smokeless use. In comparison to charcoal, they burn for longer and have a more consistent heat output, which is preferred by certain market segments such as restaurants, hospitals, and schools. EEP/SEA (2013) also noted that multiple factors beyond price per unit and price per energy output influence energy choices that lead to partial or complete substitution at the household level. Energy density, ash content, associated smoke and fumes, compatibility with cooking appliances, availability of the fuel and type of food (meal) to be prepared influence these choices.

The above findings are also related to (Emerhi, 2011) who asserted that briquettes made from materials that cost little or no money to obtain, such as newspapers or partially decomposed plant waste or sawdust, can be an alternative source of domestic and industrial energy to charcoal, firewood, gas, coal, and electricity. Depending on materials used to make the briquettes, they may burn cleaner than charcoal and firewood. Briquettes production thereby turns waste materials into fuel.

Research by the Uganda LPG Association expects Ushs 80,000 of charcoal to last 2 weeks. For the purpose of comparison, the assumption that briquettes can replace charcoal weight for weight means that Ushs 80,000 could last for between 2 and 4 weeks. According to (Ferguson, 2012), these kinds of price trends have made an economic case for briquettes which can cost between Ushs 32,000 and Ushs 40,000 for a similar 40 kg sack and last longer than traditional charcoal. 14.5% used briquettes because of easy accessibility, 21.7% used briquettes because they cook faster than wood charcoal, 7.2% said briquettes were less smoky compared to wood charcoal, and only 10.1% were involved in the process of commercial briquette making as an easy option while the least population of respondents surveyed, 2.9% said they do not use briquettes at all.

Analysis by age groups revealed that: In the age group 14-24 years: among the 24.6% of the reasons for peoples' choice of using briquettes, 13.0% said briquettes are cost effective, briquettes cook faster than wood charcoal (3.6%), and only 2.2% stated that they do not use briquettes. Age group 25-34 years: among the 29.7%, the respondents (40.0%) agreed that briquettes are easily accessed, and (0.0%) of the respondents in this age group did not use briquettes. In the age group 35-44 years: among the 23.9%, 0.0% respondents did not use briquettes, 25% said briquettes were cost effective, 30% said briquettes were readily available while 23.3% acknowledged that briquettes cook faster. Age group 45-54 years: among 10.1%, 0.7% of respondents do not use briquettes, and 13.3% agreed that briquettes cook faster. Age group 55-64 years: among the 8.0%, 0.7% had access to briquettes, 0.0% did not use briquettes, and 2.2 % said briquettes were more cost efficient to use than wood charcoal. In the last age group of 65+ years, among 3.6%, 2.2% said briquettes were cost-effective, and 0.7% said briquettes cook faster. Each age group had a member using biomass briquettes, and the reasons for their choice of using and adapting to this new energy technology were interrelated for varying age groups.

Bio-energy, apart from hydropower, is considered to be the second most significant pillar to secure energy supply, particularly in rural areas (MEMD, 2007). However, the energy consumption for the previous years has concentrated on wood charcoal and wood biomass other than the use of biomass briquettes.

IV. Conclusion

In all the comparisons between briquettes and wood charcoal, it was concluded that no matter what is being heated, more charcoal is used than briquettes. In short duration heating, for example, less than 30 minutes, the difference is not much. However, in particularly long duration heating like cooking dry beans, a lot more charcoal is required while the briquettes may be the same weight as the ones that boil water only that with water not all the briquette is utilized as the water boils before the briquette burns out. This means the briquettes maintain their energy for an extended period while charcoal burns out fast and then more is added to keep the fire going thereby increasing the demand for the wood from forests. Hence briquettes show superior performance and their availability could be improved in order to conserve the dwindling forest resources of Uganda. Briquettes were also found to be cost-effective, readily available, to cook faster and they were less smoky.

V. Recommendations

Many Ugandan households steam mashed bananas all day and use dry beans as a staple sauce and briquettes are appropriately suited to play this role due to their ability to burn for longer periods than charcoal. Restaurants also require lit fires all day to keep food warm for customers and briquettes could replace charcoal in this role while even reducing their charcoal bills and conserving forests. The long lasting ability of the briquette should be centered on in the promotion of briquettes.

References

[1] Amin, M. E. (2005).*Social Science Research Conception, Methodology and Analysis.* Makerere University, Kampala, Uganda.

[2] Bekele, W., & Drake, L. (2003). Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: a case study of the Hunde-Lafto area. *Ecological economics*, *46*(3), pp. 437-451.

[3] Byakola, T. and Mukheibir, P. (2009). *Energy Systems: Vulnerability, Adaptation, Resilience (VAR),* Regional Focus: sub-Saharan Africa, Uganda, Helio International, pp. 84.

[4] CEEDS-Centre for Energy, Environment and Development Studies (2000). *Biomass Briquette Extension, Production and Marketing.*

[5] EEP/SEA-Energy and Environment Partnership/Southern and Eastern Africa (2013). *Analyzing Briquette Markets in Tanzania, Kenya and Uganda* Report, January.

[6] Emerhi, E. A. (2011). *Physical and combustion properties of briquettes produced from saw dust of three hardwood species and different organic binders, Asaba, Nigeria.* Pelagia Research Library. Advances in Applied Science Research, 2 (6), pp. 236-246.

[7] Ferguson, H. (2012). *Briquette Businesses in Uganda*, GVEP International London, UK, pp. 31-39.

[8] MEMD-Ministry of Energy & Mineral Development (2007).*Renewable Energy Policy for Uganda*. Ministry of Energy and Mineral Development.
[9] Olof Nyström & Olle Faxälv, (2006). *Biomass Briquettes in Malawi*, Linkoping University, Institute of Technology.
[10] Sathaye J., and Tayler S., (1991). *Transition in household energy use in urban China, India, the Philippines, Thailand, and Hong Kong.* Annual Review of Energy and the Environment.
[11] UBOS (Uganda Bureau of Statistics), (2012).
[12] ULPGAS, *Shortage of LPG (cooking gas) in Uganda*, www.uplgas.org. Sept. 2011
[13] United Nations Development Programme (UNDP), (2003). *Access of the Poor to Clean Household Fuels in India*; the World Bank: Washington, DC, USA, 2003, pp. 94-125.
[14] World Resources (2001). People and Ecosystem: *The Fraying Web of Life.* WRI. Washington D. C.
[15] Yu, L., Yaoqiu, K., Ningsheng, H., Zhifeng, W. and Lianzhong, X., (2008). *Popularizing household-scale biogas digesters for rural sustainable energy development and greenhouse gas mitigation. Renew. Energy*, *33*, 2027–2035.