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A comparative performance analysis of carbonized briquettes and charcoal fuels in Kampala-urban, Uganda

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ABSTRACT

As a result of the rising energy needs and environmental concerns, carbonized briquettes have been looked at as a possible substitute source of energy for charcoal in most of the developing regions. However their use and adoption in Uganda cannot be rated amidst continued increase in charcoal demand from the ever growing urbanization. This study therefore investigated burning performance and cost in affecting briquette use. A comparative performance analysis was carried out for locally purchased carbonized briquettes made from matooke peels plus other household wastes and charcoal fuel denoted as A, B, C, and D, using a nested design. Calorific value, ash content, moisture content, burning time, and time of boil as well as cost per kilogram and per energy output, were the parameters compared. Results showed that gross calorific values were comparable for the two fuel types in the range of 4663–6517 kcal/kg. However, the average cost per energy output of briquettes as received was more than twice that of charcoal. This implies that briquettes are not worth their price since their calorific values are comparable to those of charcoal. The least expected was that shape and size of briquettes did not have influence on burning time and time of boil, an indication of briquette adulteration. Therefore further research needs to look at how the cost per energy output of briquettes can be reduced to be comparable to that of charcoal without compromising the quality. This work will contribute to monitoring policies and promote efficient briquette production methods to reduce the cost of briquettes in order to create a competitive edge against charcoal. But at the moment, charcoal users may not be attracted to briquettes due to their high cost per energy output, calling for an alternative path of household waste utilization to provide sustainable energy.

1. Introduction

As the subject of universal access to clean energy and sustainable environment continues to dominate international debates, the use of charcoal in urban households remains dominant in Sub-Saharan African countries. Karekezi's (Karekezi, 2002) submission on electricity being largely confined to high-income urban households may not hold as far as the use of electricity is concerned. This is because about 48% of the so called high-income urban households use electricity for lighting and only 1.6% use it for cooking, a Uganda case according Ministry of Energy and Mineral Development (MEMD) (MEMD, 2006) and Uganda Bureau of Statistics (UBOS) (UBOS, 2010). An indication that even those with access to electricity, the capacity to use it and pay for it is limited. With the ever growing urbanization, the demand for charcoal is projected to be about 75% in the tropical countries (May-Tobin, 2011). In Kampala, 76% of the population depends on charcoal as their main source of fuel for cooking (Ferguson et al., 2012). More so, this growing urbanization goes along with challenges of waste disposal management with over 60% of the organic waste coming from households (Ogwueleka, 2013).

In Uganda, the composition of urban waste is dominated by banana (matooke peels) at about 34% according to MEMD, (MEMD, 2012) which are said to be utilized in carbonized briquette making according to a number of sources (Anhwange et al., 2009; Natukunda, 2007; Mallimbo & Rudmec, 2009), in some literature called charcoal briquettes (Akowuah et al., 2012). Since even those with access to electricity have no capacity to pay for it, one would have hoped that these carbonized briquettes would be the possible alternative source of energy to the traditional charcoal which impacts negatively on the environment and in addition serves as a waste control strategy. But this seems not to be the trend as their adoption and use cannot be given any possible rating on top of the continued common sight of the matooke peels in the urban (Achidria, 2015). This is not to mention the 10 million tonnes of fuelwood deficit projected by 2016 (MEMD, 2005) amidst the large quantities of organic waste posing disposal challenges.

Although charcoal's contribution to Uganda's Gross Domestic Product (GDP) is around US$ 48 million, the current level of demand, coupled

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with unsustainable harvesting causes Uganda to be approaching an energy deficiency (UNDP, 2011). This calls for an alternative source of energy. Therefore, the purpose of this study was to find out why carbonized briquettes have not simulated interest among the end-users as part of the work in trying to forge a way in which the relatively abundant organic household waste can be put to use to provide a sustainable alternative source of energy to charcoal without joining the waste stream to cause pollution.

The process of making carbonized briquettes starts with biomass collection like matooke peels, drying, carbonization to produce charcoal powder, mixing charcoal powder with a binder such as starch and others use soil either as a binder or as a filler for density purposes, compressing the mixture of charcoal powder and binder in molds to produced the briquettes, drying of the briquettes and packing for sale. This is according to briquetting fact sheet of Practical Action Technology Challenging Poverty.

2. Materials and methods

2.1. Study scope

The study was focused on the briquettes in Kampala markets and charcoal from various selling points around Kampala, the capital city of Uganda. A comparative study was based on the following parameters:

i) quality analysis of the briquettes and charcoal on the market and
ii) burning time and time of boil for the briquettes and charcoal using a local ceramic stove
iii) cost-quantity analysis of the briquettes and charcoal on the market.

2.2. Experimental design

A nested design given by the model in Eq. 1 was used in this study. It is able to analyze variability between the two fuel types (briquettes and charcoal) and within. Sample categories designated as A, B, C and D each in three replications for both briquettes and charcoal which were used in experimentation were collected from different markets in Kampala. Three replicates were used as the recommended minimum number of replicates needed in experiments involving stove testing, (Bailis et al., 2007; Wang et al., 2014). All the briquette samples were carbonized but of different shapes, sizes and probably different raw materials due to differences in color as demonstrated in Fig. 1. Charcoal samples for comparison were also obtained from four different vendors from four markets to minimize the likelihood of getting samples of one supplier if bought at one location.

$$Y_{ijk} = u + p_i + \tau_{(i)j} + \varepsilon_{(ij)k} \quad (1)$$

Where Y_{ijk} is the total variation, μ is a constant, ρ_i is variation between factors and in this case briquettes and charcoal, $\tau_{(i)j}$ is variation within the factors and $\varepsilon_{(ij)k}$ is variation due to error. Eq. 1 can further be translated to Eqs. 2 and 3 for computation of the respective variations when μ is zero.

$$\text{TSS} = \text{SSB} + \text{SSW} + \text{SS}_{\text{error}} \quad (2)$$

where TSS is the total sum of square, SSB is the sum of squares between the factors, SSW is the sum of squares within the factors and SS_{error} is due to error.

$$\Sigma\Sigma\Sigma\left(Y_{ijk} - \overline{Y}.\right)^2 = m.n\sum_{i\text{-}1}^{M}\left(\overline{Y_i} - \overline{Y}..\right)^2 + n\sum_{i-1}^{M}\sum_{j-1}^{m}\left(\overline{Y_{ij}} - \overline{Y_i}\right)^2 + \sum_{i-1}^{M}\sum_{j-1}^{m}\sum_{k\text{-}1}^{n}\left(\overline{Y_{ijk}} - \overline{Y_{ij}}\right)^2 \quad (3)$$

for i = 1, 2,..,M, where M = number of factors, j = 1, 2,..,m, where m = number of locations representing the categories of samples which is equal to four for this work and k = 1, 2,..,n, where n = replication.

2.3. Cost and quality analysis

Weight of the samples whose cost was already known from the market vendors was measured using an electrical digital weighing scale of ±0.01 g sensitivity. The cost per unit weight of the samples was then calculated from the ratio of the cost of bulk to the weight of the bulk. In quality analysis burning time, moisture content (dry basis), calorific value and ash content were the parameters determined as received. Three grams of the fuel sample were weighed in crucibles and put in Gallenkamp hot box oven set at a temperature of 105 °C for16 h until there was no change in the weight of the sample. Moisture content on dry basis was calculated using the Eq. 4 according to ASTM E 871-82, (ASTM, 2013).

$$\text{MC}_{\text{dry}} = \frac{\text{Weight of the sample-Weight of oven dry sample}}{\text{Weight of oven dry sample}} \times 100\% \quad (4)$$

The weighed dry fuel samples from the moisture content tests were then put in the Carbolite muffle furnace set at a temperature of 550 °C and heated for 24 h. The crucibles with the ashed samples were then cooled in a desiccator for 2 h. The incombustible residues of the samples were weighed. The percentage ash content was calculated using the Eq. 5.

$$\text{Percentage Ash content} = \frac{\text{Weight of ash}}{\text{Original weight of the sample}} \times 100\% \quad (5)$$

Calorific values of the fuel samples were determined as per the ASTM D 2016-93 standard procedures using the oxygen bomb calorimeter. The

Fig. 1. Carbonized briquettes on the market. A — Pillow Carbonized charcoal dust briquettes; B — Cylindrical char dust briquettes; C — Pelleted char dust briquettes; D — Hollow carbonized saw dust briquettes. It is important to note that differences due to briquette composition or materials used and tree's species from which charcoal was made were not analyzed for as the vendors could not be in position to tell what materials the briquette supplier used or what tree species the charcoal supplier used. It was not also possible to get briquettes of the same size and shape from different manufacturers and this informed the choice of the nested design used. However, the researcher was able to establish that majority of briquette manufacturers use matooke peels as one of the main materials from those who supply the peels to them after gathering them from garbage sites to earn a living shown in Fig. 2.