Solid Fuel Production from Landfill Waste for Promoting Sustainable Development in Africa

[1,2]M. M. Manyuchi*

[1]BioEnergy and Environmental Technology Centre, Department of Operations and Quality Management, Faculty of Engineering and the Built Environment, University of Johannesburg, South Africa

[2]Department of Chemical and Processing Engineering, Faculty of Engineering, Manicaland State University of Applied Sciences, Zimbabwe

* mercy.manyuchi@gmail.com

[1]C. Mbohwa

[1]BioEnergy and Environmental Technology Centre, Department of Operations and Quality Management, Faculty of Engineering and the Built Environment, University of Johannesburg, South Africa

cmbohwa@uj.ac.za

[1,3]E. Muzenda

[1]BioEnergy and Environmental Technology Centre, Department of Operations and Quality Management, Faculty of Engineering and the Built Environment, University of Johannesburg, South Africa

[4]Department of Chemical, Materials and Metallurgical Engineering, Faculty of Engineering and Technology, Botswana International University of Science and Technology, P. Bag 16, Palapye, Botswana

emuzenda@uj.ac.za; muzendae@biust.ac.bw

Abstract

In the present study, the potential to produce bio pellets from organic landfill waste was investigated as a strategy to promote sustainability of landfills as well as provision of alternative clean energy source. Organic waste was first shredded then compacted to pellets. Afterwards, the pellets went through carbonization at 400 °C for 30 minutes. The organic waste and bio pellets moisture content, ash content, volatile matter, fixed carbon and calorific value were measure. The calorific value of the bio pellets was 50% higher in comparison to the organic waste. The organic waste carbonization also resulted in a 97% increase in the fixed carbon content, 50% decrease in ash and volatile content matter as well as 86% decrease in moisture content. Landfill organic waste can be converted to form bio pellets with characteristics identical to coal.

Keywords: Bio pellets, carbonization, landfill waste, solid fuel

1. Introduction

The interest on waste to energy initiatives from landfills is increasing and to date biogas has been the most type of renewable energy harnessed from landfills (Manyuchi et al., 2017a). Engineered landfills allow for separation

at source and the organic waste from the landfill prevents an opportunity for the conversion to other solids briquettes like pellets (Amaya et al., 2005; Romallosa et al., 2011). Figure 1 shows the energy potential that can be realised from municipal residue derived waste (RDF) and the treatment stages.

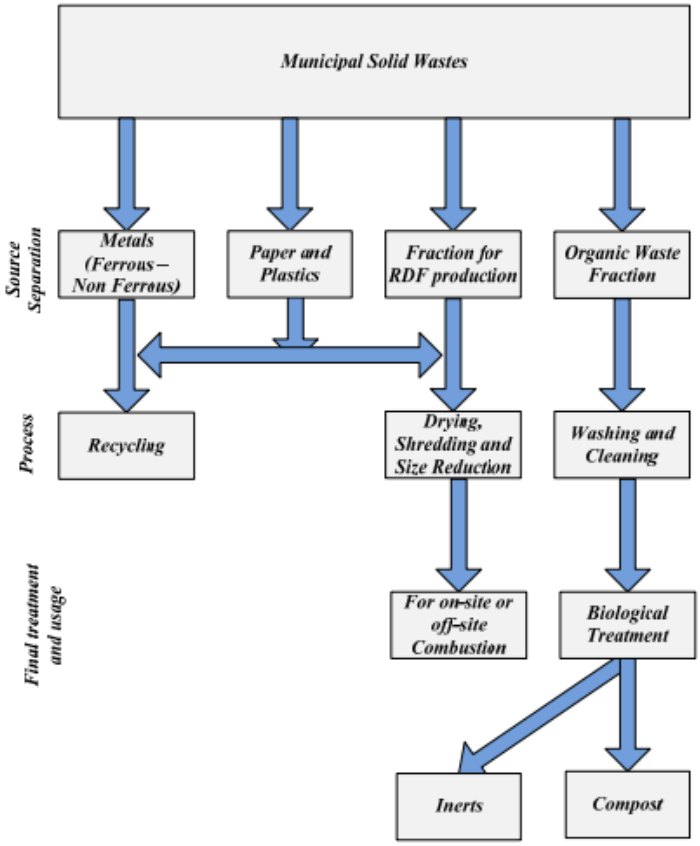

Figure 1. Residue derived fuels from landfill waste (Psomopoulos, 2014)

The production of bio pellets as an alternative source of energy has become topical due to its potential to meet the energy demands for off grid and rural communities (Voicea et al., 2013). Also of utmost importance is the waste management aspect that is realized from the production of biomass briquettes (Manyuchi et al., 2017b). Figure 2 shows a simplified process for the production of the bio pellets.

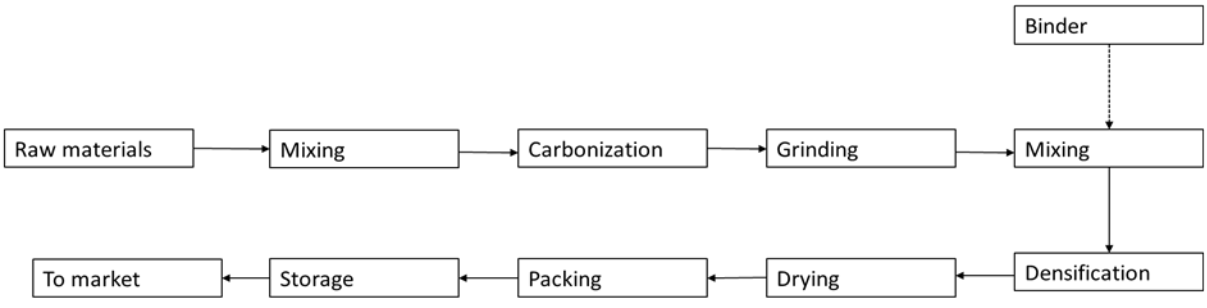

Figure 2. Bio pellets from landfill waste production process (Asamoah et al., 2006)

Bio pellets also termed biomass briquettes has several energy applications which include steam generation in boilers, heating source in bricks industry as well as domestic use. Several forms and shapes of the bio pellets exist as shown in Figure 3.

Figure 3. Biomass briquettes types (Asamoah et al., 2006)

In this study, the organic fraction of waste from a landfill was considered for the potential to produce biomass pellets that can be used as a larger domestic fuel. The study allows for exploring other opportunities for waste to energy initiatives in order to increase the life span of a landfill.

2. Materials and Methods

2.1 Materials

Organic waste was obtained from a local landfill. Moisture content was analysed by an AND moisture analyser as a percentage. The calorific values were determined by a Leco AC bomb calorimeter in mega joules per kilogram (MJ/kg). A Mermet oven was used for the ash content and volatile matter determination.

2.2 Methods

The organic waste was first homogenized by through shredding; afterwards it was compacted into pellets with size 1.5 cm by 1.5 cm using a lab made rectangular compactor that had a 12 pellet capacity. The pellets were then carbonized in a lab scale pyrolysis unit at 400 °C for 3 hours that had a venting pipe to allow for the removal of volatiles such as carbon dioxide and carbon monoxide. The results of the physicochemical parameters of the organic waste bio pellets were compared to those of the conventional coal available in Southern Africa to determine their usability as an alternative fuel. The organic waste and bio pellets were characterized for moisture content, volatile matter, ash content, fixed carbon and the calorific value. The moisture content was measured as a percentage of change in weight by heating a 5g sample at 105 °C for 10 minutes, whilst the ash content was also determined by heating the 5g sample at 550 °C for 5 minutes. The volatile matter was determined by heating the sample at 900 °C for 7 minutes. The fixed carbon content was calculated as the difference from 100% after subtraction the moisture, ash and volatile matter.

3. Results and discussion

3.1 Landfill organic waste characterization

The organic waste had an average calorific value of 12.4 MJ/kg, moisture content of 34.1%. The calorific value was on the low side hence the need for densification and carbonization. Densification of the organic waste allows for it to be closely compacted which has potential to also increase the calorific value (Amaya et al., 2005). Moisture content is an important parameter in a solid fuel and must be maintained as low as possible otherwise there is potential for decreasing the calorific value (Andrejko and Grochowicz, 2007). The fixed carbon in the organic was less than 2% and this can be attributed to the high volatile matter and ash content in the organic matter. The fixed content value can be enhanced by removal of volatiles in the organic waste (Voicea et al., 2013). A summary of the organic waste properties are given in Table 1.

Table 1. Physiochemical parameters of the landfill organic waste

Parameter	Value
Moisture content (%)	32.4-35.6

Ash content (%)	25.1-26.8
Volatile matter (%)	36.9-38.5
Fixed carbon (%)	1.4-1.8
Calorific value (MJ/kg)	11.2-13.6

3.2 Bio pellets characterization

The bio pellets produced had an average weight of 14 grams. The densification and pyrolysis of the organic waste allowed for the enhancement of the calorific value during the bio pellets production. The calorific value of the organic waste doubled to 25.1 MJ/kg carbonization and the value is comparable to the calorific values of coals found in Southern Africa (Everson et al., 2013). The carbonization process also resulted in increased fixed carbon by 97% which relates to the increase in the calorific value (Table 2). The bio pellets can be used for co firing as well as heat generation purposes.

Carbonization of the organic waste resulted in removal of volatiles in the organic waste which resulted in the ash and volatile matter decrease by more than 50% (Asamoah et al., 2006). This resulted in a solid fuel that is smoke free with minimal emissions such as carbon dioxide and carbon monoxide which have potential to cause the greenhouse gases effect. The densification and carbonization of the organic waste to solid fuels also allowed for the dewatering and drying of the bio pellets resulting in a product with a low moisture content of 6.5% allowing the bio pellets to burn effectively (Andrejko and Grochowicz, 2007). The characteristics of the organic waste bio pellets are shown in Table 2.

Table 2. Physiochemical parameters of the bio pellets

Parameter	Bio pellets
Moisture content (%)	5.4-7.6
Ash content (%)	14.3-15.8
Volatile matter (%)	18.5-19.2
Fixed carbon (%)	60.1-63.2
Calorific value (MJ/kg)	23.5-26.7

3.3 Bio pellets characteristics in comparison to coal

The bio pellets produced from the landfill organic had characteristics that were comparable to that of the standard coal in Southern Africa (Table 3). Of importance was average the calorific value which was equivalent to that of coal (25.1 MJ/kg). This high value in both fuels is an indication of the high combustion efficiency and is directly related to the fixed carbon content values.

Table 3. Physiochemical parameters of the bio pellets in comparison to coal

Parameter	Bio pellets	Coal (Everson et al., 2013)
Moisture content (%)	5.4-7.6	3.1-6.4
Ash content (%)	14.3-15.8	19.9-26.8
Volatile matter (%)	18.5-19.2	19.1-23.1

Fixed carbon (%)	60.1-63.2	49.8-60.1
Calorific value (MJ/kg)	23.5-26.7	21.8-28.3

4. Conclusion

Landfill organic waste can be converted to solid fuels with high calorific values of almost 25.1 MJ/kg through carbonization. The high calorific values are due to increased fixed carbon content and lowered moisture, ash and volatile matter contents during the production process. The bio pellets produced can be used in place of coal due to their similar properties thereby promoting waste to energy initiatives.

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