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Characterization of Ugandan biomass wastes as the potential candidates towards bioenergy production

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ABSTRACT

Biomass waste can be characterized to identify its use in bio-energy production. This study aimed to characterize *Mbwazirume* peel (MP) and *Nakyinyika* peel (NP) biomass using various analyses such as proximate and ultimate, TGA, FT-IR, AAS, and SEM-EDS. This was in order to assess their suitability for bio-energy application in Uganda. Results indicate that MP biomass shows higher VM 69.988%, FC 13.582%, ash content 5.825%, and HHV 18.28 $MJ\text{-}kg^{-1}$, and shows lower moisture content 10.605%, nitrogen (N) 5.78%, oxygen (O) 46.74% and sulfur 0.30%. The decomposition of hemicellulose mainly takes place at 100–250 °C, cellulose at 300–500 °C, and lignin at 500 °C and above. The spectrometer results exhibit various functional groups which are related to C=C, OH, C=O, and C–O–C. The heavy metals (HMs) results for both samples indicate that Cu, Cd and Pb were low, and Zn was high. These toxics may not affect the environment due to their low amount of eco-toxicity and bioavailability. The SEM images show the presence of starch granules and irregular particles with heterogeneous morphology. This might justify the occurrence of high cellulose content due to additional restrictions on molecular motion. During the EDS analysis, the elements found in both ash residues were ordered as follows: O > K > C > Cl > Mg > P for MP, and K > Cl > Mg > P > Al for NP. All these properties proved that MP biomass is more suitable as a potential application for bio-energy.

1. Introduction

Banana is among of the most consumed fruits in the world, yet there is little industrial use for its peel, which constitutes 30%–40% of the weight of the fruit [1]. Uganda is ranked the second largest producer of bananas at 11.1 m tons per year, after India with 29.7 m tons of bananas produced per year [2]. Uganda is the number one consumer of bananas at 240 kg per capita per annum [2]. This means that bananas are key part of many families' everyday diet, which in return generates considerable quantities of banana peels each day all year round [3]. There are different types of bananas grown in Uganda for food consumption. These have been classified as green bananas (*Matooke*), plantain, and yellow or sweet bananas [1]. *Matooke* (*Musa-AAA-EA*) is a variety of banana indigenous to Uganda, which is the most essential staple food crop for human consumption. It comes from the family of bananas known as East African highland bananas. It appears to be green in color and thick at the midsection [4], and cannot be peeled in the same way as yellow bananas. These peels are used as animal feed or as local briquettes.

Despite the usage, about 61.8 kg per capital per annum of *Matooke* peels produced in Uganda become waste, due to the lack of sufficient structure and indiscriminate dumping. This huge amount of waste leads

Abbreviations: AAS, Atomic absorption spectroscopy; ASTM, American society for testing and materials; CO_2, Carbon dioxide; Cu, Copper; Cd, Cadmium; CF_Z, Content of HMs found in the residue; DTG, Derivative thermogravimetry; DIN, Deutsches institute für normung; EDS, Energy dispersive X-ray spectrometer; FC, Fixed carbon; FT-IR, Fourier-transform infrared spectroscopy; LCB, Lignocelluloses biomass; GHG, Greenhouse gas; H_2O, water; HMs, Heavy metals; MC, Moisture content; MP, *Mbwazirume* peel; NP, *Nakyinyika* peel; HHV, Higher heating value; M_f, After heat treatment; M_i, Before heat treatment; N, Nitrogen; NEMP, National environment management policy; NEP, National energy policy; NO_x, Nitrogen oxides; NOGP, National oil and gas policy; O, Oxygen; Pb, Lead; RETs, Renewable energy technologies; REP, Renewable energy policy; SEM, Scanning electron microscopy; SO_2, Sulfur dioxide; TGA, Thermogravimetric analysis; T_{idt}, initial decomposition temperature; TC_Z, Total content of HMs in the residues; UIRI, Uganda industrial research institute; UNBS, Uganda national bureau of standards; VM, Volatile matter; Zn, Zinc.

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