



Proximate and Chemical Analyses of Selected Agricultural Wastes Used for Biogas Production

A.D TAMB UWAL and C. OGBIKO*

Department of Pure and Applied Chemistry, Faculty of Science, Usmanu Danfodiyo University Sokoto, Skoto State, North –Western Nigeria

* Corresponding author E-mail: cyrilogbiko@gmail.com, cyril.ogbiko@udusok.edu.ng

Abstract

Keywords:

Agricultural Wastes,
Biogas,
Proximate,
Slurry,
Substrate.

Due to the rising cost of fossil oil accompanied with pollution problems associated with petroleum and allied products have led to the search for alternative sources of energy. This research was conducted to determine the proximate and chemical analyses of fresh and spent slurries with a view of determining their suitability for energy production. The samples were analyzed according to standard analytical techniques. The proximate and chemical analyses of the substrates hold promise as a potential biogas source as evidenced by the 4773, 6535, 6684, 3834, 4096 and 6199 kcal/kg for the pumpkin, plantain, banana, spinach, watermelon and synergized mixture respectively. The spent slurry offers promise as an excellent source of plant nutrients since it could serve as a source for bio-fertilizer production.

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INTRODUCTION

The world as at today is plagued with mounting energy and waste crisis brought as a result of rapid growth of human population and uncontrolled and unmonitored urbanization. While energy is a basic tool for development, developing countries like Nigeria faces additional dilemma regarding environment pollutions due to the heavy dependency on biomass and access to energy resources presents challenges to human health and economic development (Mshandete and Parawira, 2009). As a result of man increasing demand for energy, deforestation in search of wood fuel or charcoal has quadrupled hence not sustainable on the long term. Hence, any attempt at reducing wood fuel consumption should be encouraged as it will invariably lead to a reduction in deforestation, environmental protection as well as curbing the emission of greenhouse gases (Odeyemi, 1979).

Biomass such as agricultural wastes, municipal waste, and green waste (kitchen waste) present a promising renewable energy opportunity (Sagagi *et al.*

et al., 2009). In most cities in Nigeria, waste is disposed off as landfills or discarded indiscriminately which causes health hazard and diseases like malaria, typhoid, cholera etc. (Adeyosoye *et al.*, 2010), hence biological conversion of biomass to methane has received an increasing attention in recent years.

Over the years, several techniques have been used for the conversion of organic materials to biogas and this has been successfully used in meeting the energy needs in urban and rural areas. In United States there has been considerable interest in the process of anaerobic digestion as an approach to generating a safe clear fuel as well as source of fertilizer (Garba and Sambo, 1995). The use of rural wastes for biogas generation, rather than directly used as fuel or fertilizer, offers several benefits such as the production of energy resource that can be stored and used more efficiently in the production of stabilized residue (sludge) that retains the fertilizer value of original material and the saving of energy required to produce equivalent amount of nitrogen-containing fertilizer by synthetic process (Sagagi *et al.*, 2009).

Biogas is a flammable gas produced when organic materials are fermented under anaerobic condition. The gas is called by several other names such as: dung gas, marsh gas, gobar gas, sewage gas and swamp gas (Dangoggo and Fernando, 1986). Table 1 illustrates the major composition of biogas and their concentration by volume

Table 1: Composition of biogas (Abubakar, 2017)

Components	Concentration (by volume)
Methane (CH ₄)	55- 60%
Carbon dioxide (CO ₂)	35- 40%
Water (H ₂ O)	2- 7%
Hydrogen Sulphide (H ₂ S)	20- 20.000 ppm (2%)
Ammonia (NH ₃)	0- 0.05%
Nitrogen (N)	0-2%
Oxygen (O ₂)	0 -2%
Hydrogen (H)	0-1%

The rate of biogas production depends the nature of the substrate, temperature, pH, loading rate, toxicity, stirring, nutrients, slurry concentration, digester construction and size, carbon to nitrogen ratio, retention time, alkalinity, initial feeding, total volatile acids, chemical oxygen demand (COD), total solid (Ts), volatile liquids among others (Abubakar, 2017). This paper presents results of the production of biogas from spinach stalk residue as well as comparing the proximate parameters of the substrate and slurry prior to and after the biogas production.

MATERIALS AND METHODS

Source of Samples

The materials used for this research work were vegetable and fruit wastes collected from various locations within Sokoto metropolis. While pumpkin, spinach stalk, banana and plantain peel were collected from Ramin Kura market, fresh watermelon residues was collected from Miyetti Allah area both in Sokoto metropolis.



Figure 1: View of procured vegetable and fruit waste

Sample Treatment

The fresh samples were sorted and chopped manually into smaller sizes to ease the digestion process. They were packed into clean and labelled black polyethylene bags for onward use for the study. The study commenced immediately at the Sokoto Energy

Research Centre central laboratory, Usmanu Danfodiyo University Sokoto, Sokoto State Nigeria.

Chemical analysis of the fresh wastes

The fresh wastes were each analyzed for their percentage moisture, ash and volatile solid according to the procedure described by AOAC, 1990. They were further analyzed for their phosphorus, potassium, carbon, total nitrogen contents according to the procedures described by Egbekeun and Ehieze (1997) and Bagudo, 2007 respectively. The pH and calorific value of the freshly prepared and spent slurry as well as the calorific value of the biogas produced was determined. The percentage moisture, ash, volatile solid, carbon, total nitrogen, phosphorus (mg/kg), potassium (mg/kg) of the spent slurry was also determined. All parameter was performed in triplicate.

RESULTS AND DISCUSSIONS

Moisture and Ash Contents

The result of the moisture and ash contents of the fresh and spent slurries of the substrates is presented in figures 2 and 3.

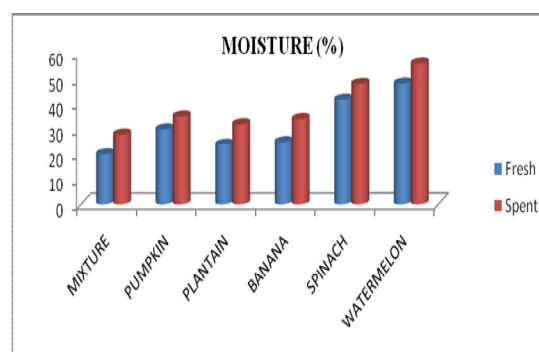


Figure 2: Comparative percentage moisture content of the fresh substrates and spent slurry

Moisture content is simply the water content present in a sample. It is favorable for biogas production since high moisture content will help in early digestion which invariably will lead to biogas production (Grzegorz *et al.*, 2015; Bagudo *et al.*, 2008). Sadaka and Engler (2003) reported that water content is an important parameter affecting anaerobic digestion of solid wastes because water makes it possible for the movement and growth of bacteria facilitating the dissolution and transport of nutrient as well as reduces the limitation of mass transfer of non-homogenous or particulate substrate. The result showed that the moisture content of the digestate increased for all treatment as the digestion proceeds. This is in agreement with the findings of Yadav *et al.*, 2014 which reported the physicochemical properties of *Jatropha* seed cake before and after anaerobic digestion. This however differ from the report of

Tumutegereize et al., 2011 who reported that optimization of biogas production from banana peels.

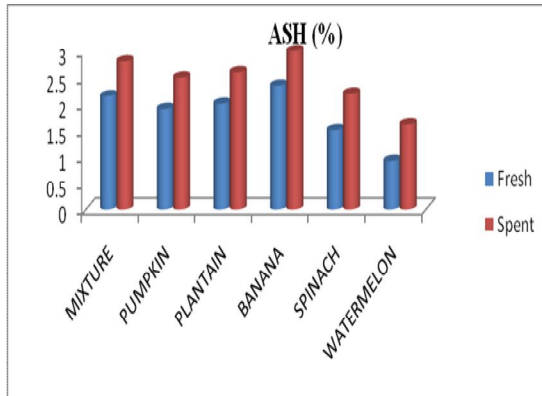


Figure 3: Comparative percentage ash content of the fresh substrates and spent slurry

Ash content determination is significant in biogas production because it reveal the elemental content of N, P, K etc present in the sample. The increase in the ash content of the digestate (spent slurry) when compared to the fresh substrate is in agreement with the findings of Ezekoye et al., 2011 and Bagudo, 2007 who both reported the influence of retention time on biogas production from agricultural wastes.

Macronutrients Composition

The amount of macronutrients (N, P and K) content of the fresh and spent slurries of the substrates is presented in figures 4 – 6.

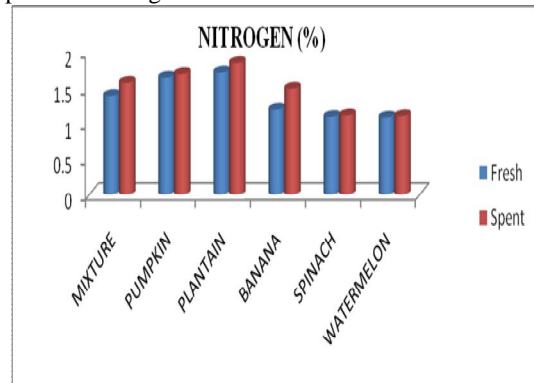


Figure 4: Comparative percentage nitrogen content of the fresh substrates and spent slurry

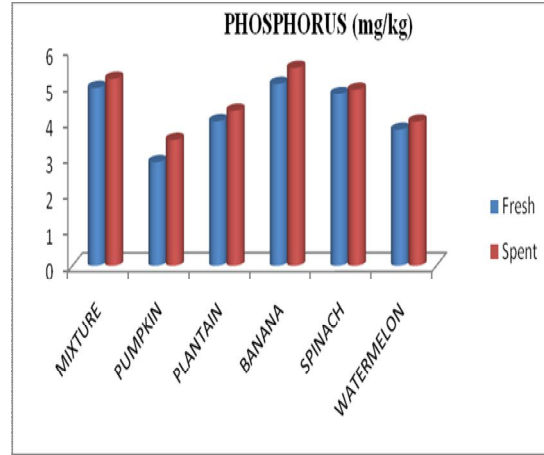


Figure 5: Comparative phosphorus (mg/kg) content of the fresh substrates and spent slurry

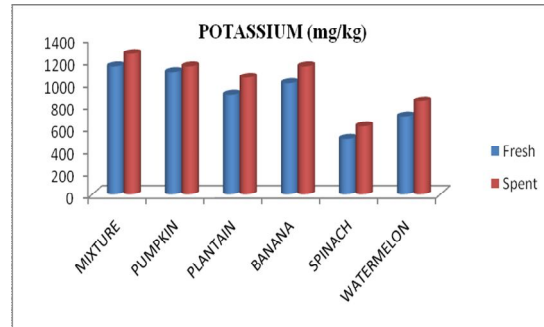


Figure 6: Comparative potassium (mg/kg) content of the fresh substrates and spent slurry

These macronutrients are very important to enhance process stability and maintain a stable operation for anaerobic digestion of municipal solid waste (Kayhanian and Rich, 1995). The result shows that the macronutrients all increased during the anaerobic digestion process. The results is in agreement with the report of Sagagi et al., (2009) and Garba (1998) who worked on the same samples as well as that of Ezekoye et al., 2011 who reported the increase in phosphorus and potassium but a decrease in nitrogen when the effect of retention time on physicochemical parameters was studied. The findings thou from the findings of Yadav et al., 2014 who reported the physicochemical properties of Jatropha seed cake before and after anaerobic digestion. These finding thus confirmed that the digested slurries could serve as an excellent fertilizer for agricultural purpose.

Organic Matter Content

The results of the volatile solid (VS) and organic (carbon) content of the fresh and spent slurries is shown in figures 7 and 8.

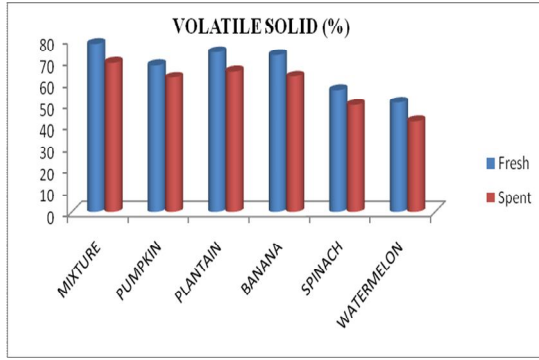


Figure 7: Comparative percentage volatile solid content of the fresh substrates and spent slurry

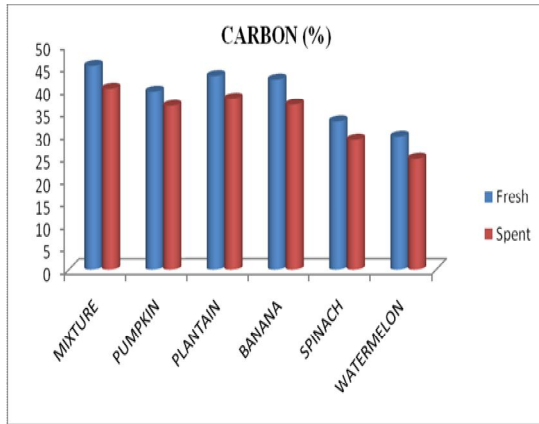


Figure 8: Comparative percentage carbon content of the fresh substrates and spent slurry

Volatile solids are the solids that are lost on ignition of the dry solids at 55°C centigrade. VS are responsible for biogas production. The quantity and rate of biogas yield depend on the amount of volatile solids present in the wastes and their digestibility. (Ezeonu, 2005). Volatile solid was found to decrease gradually during the retention period. This implies that a lot of the substrate would be required per unit volume of digester for biogas production as suggested by Mattocks (2002). The findings agrees with Tumutegyereize et al., 2011, Ezekoye et al., 2011 and Yadav et al., 2014 who reported similar decrease during anaerobic digestion. Organic matter content of substrates influences their biogas yield. Organic carbon content reduction occurred during the digestion process because microbes acquire carbon from their food so samples with higher organic matter tend to produce more biogas as reported by Bagudo et al., (2008). The reduction of C by anaerobic processes was therefore probably limited to the production of organic acids, H₂ and CO₂ by facultative bacteria (Hobson et al., 1981). Thus continuous process of feeding is required for continuous biogas production because the carbon compounds are converted to the CH₄ and other gases like CO₂. According to Richard and Wilkie (Richard,

1996; Wilkie 2005), anaerobic bacteria do not or very slowly degrade lignin and some other hydrocarbons in the absence of carbon.

pH and Calorific Value of Substrates

The pH of samples is one of basic parameters that affect biogas production. The result of the pH of the fresh and spent slurries as well as the mean calorific value produced from each substrates is shown in figures 9 and 10.

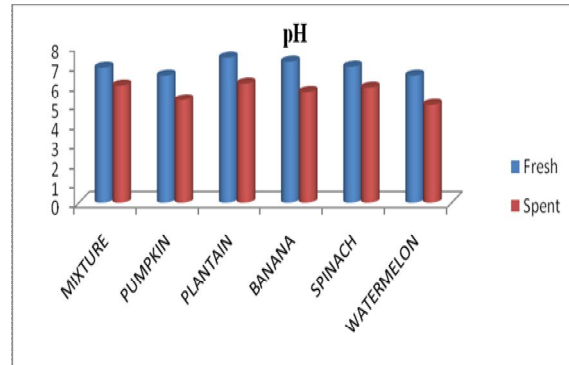


Figure 9: Comparative pH of the fresh substrates and spent slurry

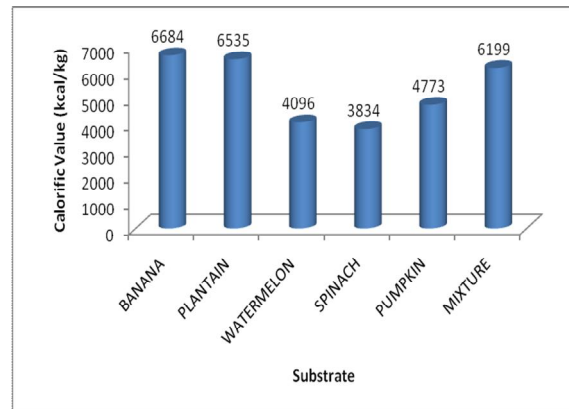


Figure 10: Mean calorific value for each substrate

The pH of the fresh substrates decreases during the retention period because as digestion commences there is bound to be the formation of sulphide in the slurries due to the breakdown of biodegradable sulphur containing organic and inorganic compounds as well as the formation of fatty acids by acetogenic methanogens which brings about a decrease in its pH (Bagudo, 2007). The observed pH is in agreement with the report of Yerima et al., 2001 who stated that for biogas generation the methanogenus grow well when the pH is in the range of 6.8 – 7.8 and that the pH range for optimum biogas production has been reported as 6 -7 by Garba and Sambo, (1992). The calorific value of the substrates is in the order synergized mixture > banana > plantain > pumpkin > watermelon > spinach. This confirms that the

substrates have a good potential for generating biogas as evidenced by their heating ability.

Fertilizer Potential of Spent Slurries

The results of the N, P and K as shown in figures 4, 5 and 6 respectively shows the fertilizer potential of the substrate. The fresh and spent slurries gave a percentage range of 1.09 to 1.72% and 1.11 to 1.85%, 2.89 to 4.95 mg/kg and 3.50 to 5.50 mg/kg as well as 500 to 1150 mg/kg and 350 to 1260 mg/kg for nitrogen, phosphorus and potassium respectively. These findings are in agreement to the findings of Sagagi *et al.*, (2009) and Garba (1998). The results confirmed that the spent slurry is a better fertilizer potential when compared to the undigested slurries. This is due to the presence of microbes confirmed to be present in the digested slurry.

CONCLUSION

The substrates utilized for this research though considered as waste have been shown not only to be a potential for biogas production but also a promising feedstock for bio-fertilizer used for soil fertility improvement.

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