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EFFECT OF PRETREATMENT ON *Typha* BIOMASS FOR BIOGAS PRODUCTION

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ABSTRACT
Plant biomass as an alternative energy source serves as a viable option for improving sustainable development and reducing greenhouse gas emissions. However, the tight bonding within its constituents may hinder anaerobic digestion, thus, requires pre-treatment to break down the complex polysaccharide structure into simpler disaccharide and monosaccharide sugars to facilitate digestion and enhance the production of biogas. The research determined the effect physical and chemical pre-treatment methods of Typha biomass for biogas production. Characteristics determined include; carbon-nitrogen (C-N) ratio for Typha biomass, temperature, pH, total solids (TS) and volatile solids (VS) of slurry formed by mixing the biomass with cow-dung in ratio 1:1. The volume of biogas produced was determined by water displacement method using an anaerobic digester while the mass balance approach was used to estimate the biogas yield from the TS/VS lost. Results indicated 31.6 C-N ratio; pH of 6.7; Temperature of $32.4^{O}C$ and TS of 11.3%, which falls within suitable ranges reported for biogas production. The volume of biogas produced was 180 cm^3, 235cm^3 and 118cm^3 for control, physical and chemical pre-treated samples respectively. Similarly, the biogas yield was 21mg/l, 15mg/l and 48mg/l for control, physical and chemical pre-treatment respectively. Hence the findings revealed physical pre-treatment as the best pre-treatment method for biogas generation from Typha biomass in relation to chemical pre-treatment and untreated Typha biomass.
Keywords: Typha biomass, Biogas, Pretreatment

INTRODUCTION

Energy is essential for enhancing economic development and improved quality of life. Fossil fuel has been a major energy resource, which accelerated global economic growth, agriculture and prosperity (Sun *et al*., 2019; Breckner and Sunder, 2019). However, rapid industrialization and urbanization increases the demand of these fossil fuels over the decades, leading to environmental degradation. Among the various sources of energy being explored, biomass offer one of the best alternative energy source, as it present a viable option for improving sustainable development through energy security and reducing the emission of greenhouse gases (Manyi-Loh *et al*., 2013).

Biomass is a renewable energy source developed from living plant and animal; it is used for the production of various biofuels, including biogas. Biofuel as an alternative to fossil fuel, and can be produced from several different biomass feedstocks. The feedstocks used for biofuels production are mainly plant biomass or waste generated from agricultural, domestic and industrial activities (Kang *et al*., 2014). It has been reported that biofuels produced from the biomass resources have the potential to cut down greenhouse gas emissions by 86% (Nikiema *et al*., 2022). Biomass such as agricultural and forestry residues, herbaceous or woody crops, terrestrial and aquatic weeds, among others are of unique environmental, economic, and strategic benefits (Chandel *et al*. 2010; Khammee *et al*., 2021). Huber and Dale (2009) reported weedy cellulosic biomass such as *Eicchornia crassipes, Lantana camara, Prosopis juliflora, Saccharum spontaneum,* and *Typha latifoli*a, as promising and cheaper feedstocks for biofuel production. Similarly, Mukhtar and Abdullahi (2020) reported *Typha* biomass as a promising feedstock with high potential for biogas production.

As an iconic wetland plant, *Typha* rapidly invades habitats due to its high growth rate and rhizomatic expansion, usually resulting in a wide range of negative ecological and agricultural impacts (Bansal *et al*., 2019).

Typha invasion greatly affects agricultural productivity in many parts of Northern Nigeria, especially the paddy areas of Southern Kano and Northern Jigawa, where it chokes waterways, causing a lot of inconveniencies (Mukhtar and Abdullahi, 2020). The production of biogas from *Typha* biomass would serve as an alternative management system, thus enhance access to affordable energy and boost economic growth in the affected areas (Yusuf *et al.*, 2022). However, pre-treatment remains one of the most important determinants in successful production of biogas from lignocellulosic biomass of plants such as *Typha* species.

Many approaches have been used in the pretreatment of plant biomass for biofuel production, including physical, chemical and biological methods. The current research was aimed at evaluating the effect of physical and chemical pre-treatment methods on *Typha* biomass for biogas production.

MATERIALS AND METHODS

Sample Collection and Preparation

Above ground biomass of *Typha* species was collected from *Typha* invaded area at Gadon Kaya, along BUK Road, Gwale Local Government Area Kano, and then transported to the Department of Biological Sciences, Bayero University Kano. The samples were washed with water to remove soil debris, chopped into smaller pieces and air-dried at room temperature as adopted by Mukhtar and Abdullahi, 2020. About 50g of the sample was weighed and grinded to powdered form for determination of biogas properties, while the remaining samples were divided into triplicate for pre-treatment processes.

Determination Carbon- Nitrogen (C/N) Ratio

Prior to the pre-treatment processes, determination of carbon and nitrogen concentration in the *Typha* biomass sample and cow-dung sample was conducted using standard procedures of Walkley and Black as described by Gelman *et al.* (2011) and Kjeldahl method as described by Tolesa *et al*. (2015), respectively. The relationship between the amount of carbon and nitrogen present in organic materials is expressed in terms of the Carbon/Nitrogen (C/N) ratio.

Pretreatment of *Typha* Biomass Sample

Physical and chemical pretreatment methods were comparably employed to break down the complex lignocellulosic structure of the *Typha* biomass into simple reducing sugars. The powdered sample was divided into three portions; the first was for physical, while the second was for chemical pretreatment; the remaining one as control. The physical method used in the study involves heating the sample in an oven at temperature of 140^{o}C for 12 hours as described by Maurya *et al.*, (2015), while chemical approach was carried out by soaking the powdered sample in 5% tetraoxosulphate (vi) acid (H_2SO_4) for 2 hours and its neutralization using potassium hydroxide (KOH) as described by Maurya *et al.,* (2015). (dilute KOH). The third (last) portion of the sample was not subjected to any pretreatment, thus it served as control.

Slurry Preparation

The slurry preparation was adopted as described by Eze and Ezeokonkwo (2018), with slight modification in the ratio of the mixture and water. Fifteen gram (15g) from each portion of the pre-treated *Typha* samples and the control sample were mixed separately with 15g each of crushed cow dung sample and 500ml of distilled water was then added to form the slurry. The pH and temperature were determined using digital pH meter (3510 JENWAY, UK) and thermometer (PM-K,PAMAENS, Shangai, China), respectively.

Experimental Setup

Three local anaerobic digesters were constructed using plastic bottled containers. A rubber hose was use to connect each of the digesters to a cylinder immersed inversely into water container to determine the volume of biogas generated by water displacement method. The slurry was fed into the digesters occupying about 75% as adopted by Deressa *et al* (2015).

Determination of Biogas Properties

Total solids (TS)

Total solid was according to the method described by Alhassan *et al*. (2020). An unknown quantity of slurry was placed in 500ml-capacity beaker with a known weight and weighed. This was then placed in an oven maintained at 105°C for 24 hours. The weight of the beaker containing the slurry after drying was weighed again. Percentage of TS was calculated by using the formula shown below:

%TS = x 100

Where W_1 = weight of an empty beaker; W_2 = weight of beaker + fresh slurry; W_3 = weight of beaker + dried slurry.

Volatile solids (VS)

Volatile solid was calculated as described in Alhassan *et al*. (2020). Three gram (3g) of the oven dried slurry sample was weighed (B) in an empty crucible (A) and heated to 550°C for an hour in the muffle furnace to constant weight (C). Per cent VS was calculated by using the formula given below:

%VS = x 100

Biogas Yield

A mass balance approach was used to estimate the theoretical biogas yield from the TS/VS lost as adopted by Deressa, (2015). The final TS/VS value after digestion was subtracted from the initial TS/VS value before digestion to obtain the TS/VS lost, which was presented as litres of biogas produced per gram.

ost =

RESULTS AND DISCUSSION

From the results, the overall C/N ratio of *Typha* biomass-cow dung mixture was 31.6, which falls within the recommended range of 25 to 35 for optimum anaerobic digestion process (Chu *et al.*, 2021). Hence, if C/N ratio is very high, the nitrogen will be consumed rapidly by methanogens for meeting their protein requirements and will no longer react on the left over carbon content of the material; as a result, gas production will be low. On the other hand, if the C/N ratio is very low, nitrogen will be liberated and accumulated in the form of ammonia (NH_4), which increases the pH value of the content in the digester, and becomes inhibitory to microbial growth and metabolism (Yoon *et al.*, 2014). The optimum biogas production is achieved when the pH value of input mixture in the digester is between 6 and 7 (Nikiema *et al.,* 2022). Hence the pH of 6.7 was recorded for the slurry is suitable for the biogas production. Anaerobic digestion is strongly affected by temperature (Hong *et al.,* 2020). Ciowabla (2012) recommended a temperature range of 20-37°C with optimum of 35°C for biogas production. The Slurry temperature of 32.7 from the current study also favours anaerobic digestion for biogas production (Alhassan *et al.*, 2020). Total solids (TS) concentrations of a feedstock provide useful information about biogas yield that can be expected (Orhorhoro *et al.*, 2017). To achieve a higher specific biogas yield efficiency, Jeppu *et al.* (2022), recommended using lower total solids of around 4%–6.7% for biogas plants compared to the conventionally used total solids of 8%–10%. However the TS of 11.3% from the current study was above the recommended range. Nikiema *et al.* (2022) reported reasonable biogas yields were possible even at TS of 14% and suggested best performance at TS of 8%.

Table 2 shows the TS and VS lost in addition to the theoretical biogas yield under different treatment conditions. Reduction in volatile solid concentration, in relation to the total solid, determines the theoretical biogas yield (Deressa *et al.*, 2015). The total solid in the acid-pretreated sample reduced from 10.8% to 9.7% with corresponding decrease of volatile solid

Several factors including pH, temperature, hydraulic retention time (HRT), carbon-nitrogen ratio, total solids and volatile solids generally affects the performance of an anaerobic digester for biogas production Yoon *et al.* (2014). Table 1 shows the characteristics of the slurry in addition to the carbon-nitrogen ratio of the *Typha* biomass. The relationship between the amount of carbon and nitrogen present in organic materials is expressed in terms of the Carbon/Nitrogen (C/N) ratio.

from 64.7% to 63.7% after 4 weeks hydraulic retention time, generating 0.015 g/l (15mg/l) of theoretical biogas yield (TBY). On the other hand, the TS in the oven-pretreated sample reduced from 10.4% to 7.2%, while VS reduced from 64.2% to 62.9%, after same period, generating 0.048 g/l (48mg/l) of biogas. Meanwhile, in the control sample, the TS reduced from 11.3% to 9.6% with corresponding decrease in VS from 65.3% to 64.4%, generating 0.024 g/l (24mg/l) of biogas. From the result it is evident that acid-pretreatment shows the lowest biogas production when compared to the control and oven-pretreated sample as seen in figure 2. Similarly, in figure 1, the biogas production from water displacement method produced 118ml, 235ml and 180ml for acid-pretreatment, oven-pretreatment and control, respectively, which also shows a similar trend as in the theoretical biogas yield. The lower biogas production in the acid-pretreated sample had to do with production of toxic by-products as a result of reactions between the acid and base as well as the chemical components of the plant materials, which might have affect the growth of microorganisms involved in biogas production (Alhassan *et al.*, 2020). However, the higher yield of biogas in oven-pretreated sample indicates that the temperature applied was capable of hydrolyzing the complex lignocellulosic plant materials in simple sugars that can be used by microorganisms for the growth and metabolism (Alhassan *et al.*, 2020), thus dictates the suitability of the pretreatment method for biogas production.

The physical pretreatment method having a higher biogas yield than the chemical pretreatment is in line with the findings of Kouzi *et al.* (2020), whom also reported heating at 75°C produced the best biogas yield in relation to that of acid alkali treatment. In a similar study by Rafique *et al.* (2010), the effect of pre-treatments (thermal, thermo-chemical and chemical pre-treatments) on biogas and methane production revealed that thermo-chemical pretreatment has the highest effect on biogas and methane potential than thermal pretreatment. However, the chemical pretreatment showed less performance in relation to the physical (thermal) pretreatment, which is in harmony with the current study, but has revealed higher biogas production compared to its control counterpart, which contradicts the findings from this study. This could be as a result of the differences in the acid and base solutions used in the pretreatments.

Table 1: *Typha* species / Slurry Characteristics

PROPERTIES	VALUES	RECOMMENED RANGE
Carbon/Nitrogen	31.6	22 – 30 (Nikiema *et al.*, 2022)
Slurry pH	6.70	6.5 – 7.5 (Yoon *et al* ., 2014)
Slurry Temperature (ºC)	32.7	20 – 37 (Cioabla *et al.,* 2012)

Tabe 2: TS/VS Lost and Theoretical Biogas Yield under Different Treatment Conditions

	Physical			**Chemical**			**Control**		
Parameters	Initial	Final	Reduction	Initial	Final	Reduction	Initial	Final	Reduction
TS	10.4	7.2	3.2	10.8	9.7	1.1	11.3	9.6	1.7
VS	64.2	62.9	1.3	64.7	63.7	1	65.3	64.4	0.9
TS/VS	0.162	0.114	0.048	0.167	0.152	0.015	0.173	0.149	0.021

Key: TS-Total solids, VS-Volatile solid

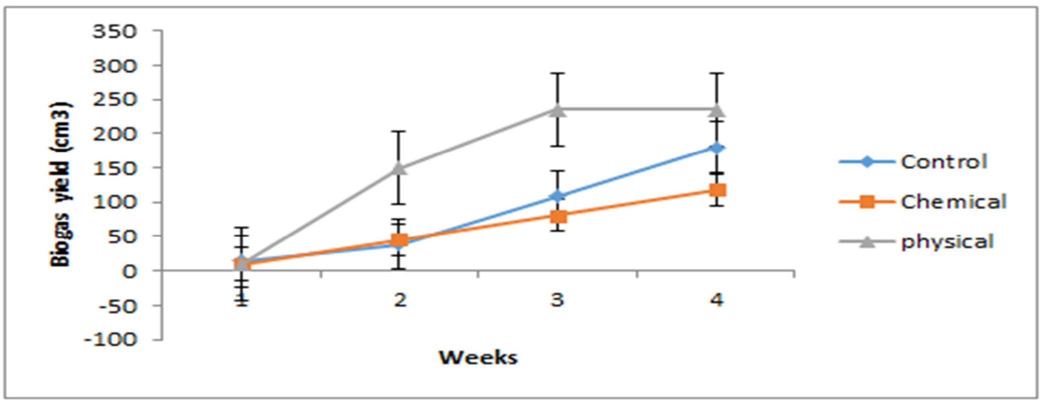

Figure 1: Biogas Yield (cm³) from Water displacement Method

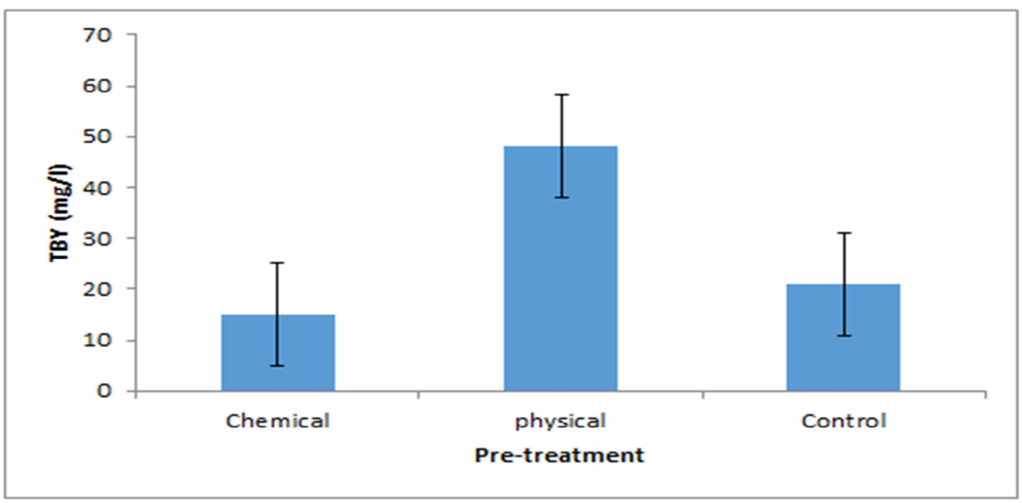

Figure 2: Theoretical Biogas Yield of *Typha* species

CONCLUSION

The production of biogas from *Typha* biomass was found to be affected by the type of pre-treatment employed to hydrolyse its complex lignocellulosic structure. The characteristics of the feedstock (*Typha* biomass) were observed to be within suitable ranges reported for efficient biogas production. The findings further revealed that physical pre-treatment method, which involves the use of heat, produced the highest biogas yield in relation to chemical pre-treatment, which produced biogas lower than that of the control samples. Hence further studies on pre-treatment under various temperature range should be evaluated for determining a recommended temperature range for efficient biogas production from *Typha* biomass.

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