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PLANT EXTRACT ADDITION FOR IMPROVED METHANE POTENTIAL OF TUBER PEEL

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ABSTRACT
The percentage yield of methane in biogas ranges from 40 – 70 %, which is relatively low when compared to natural gas whose methane composition is about 90 %. Improving the methane yield will increase the efficiency of the biogas to some extent. As a result, the use of plant additives is employed to improve the methane gas yield of the biogas produced. Methane gas production from starch-rich tuber peel was investigated at laboratory scale using a batch anaerobic digester of two litres working volume at mesophilic temperature. The digesters were fed with slurry of dry tuber peel and operated for sixty (60) days. Initially, 42 % methane production was recorded. The effect of the volume (100, 300 and 500 cm^3) of aqueous extracts of soya, neem and water hyacinth on methane gas yield was also studied. An increase in methane production over the control was recorded in all the digesters. Significantly higher levels of methane gas production were observed in the digesters to which 500 cm^3 of aqueous extract was added with the neem extracts recording the highest.

Keywords: Plant extract, Methane, Cassava peel, Digester and Aqueous.

INTRODUCTION
Energy is vital for social and economic development of every society. It is required to meet basic human needs (e.g., lighting, cooking, space comfort, mobility and communication) and to serve productive processes. Even though conventional sources, such as oil, natural gas and coal meet most of the energy demand at the moment, they are associated with progressive release of greenhouse gases. In this regard, renewable energy resources appear to be one of the most efficient and effective solutions as they provide us with excellent opportunity for mitigation of greenhouse gas (GHG) emission and global warming reduction by replacing conventional energy sources. Some renewable energy sources (i.e., solar, hydroelectric, biomass, wind, ocean and geothermal energy) are inexhaustible and offer many environmental benefits compared to conventional energy sources (Hepbasli, 2008). Conversion of biomass to energy (bioenergy) will be a good alternative with benefits such as job creation, rural economy development and improvement in environmental quality (IPPC, 2010). Also, biomass has no geographical limitation and can be processed to biogas using local technologies. Bioenergy production in form of biogas is suggested as a beneficial route to sustainable energy which is cleaner than fossil fuels with lesser GHG emissions. Biogas is a gas generated when organic matter is broken down in a closed system in the absence of oxygen (anaerobic digestion). It constituents are methane, carbon dioxide, and traces of other gases like H_2S, NH_3, H_2 and N_2 (Zain and Mohammed, 2018). Biogas has wide range of uses which include heating, electricity, and fuel (Achinas *et al*, 2017). The quality of biogas produced from organic waste materials does not remain constant but varies with the type, composition and period of digestion of the substrate as well as the percentage of methane and hydrogen sulphide gas present (Nwokem *et al.* 2017). However, factors like substrate composition, pH, temperature and pressure (Liu, 2003) determine the ratio of methane in biogas.

Tuber peel biomass is a potential feedstock for biogas production. A number of works have reported cassava to be rich in starch and carbohydrate (Moshi *et al*., 2014, Anyanwu *et al*., 2015, Sawyerr *et al*., 2018) than some crops. This offers huge potential as feedstock for biogas production with multiple benefits which include (containing high quantities of soluble organics and fast digestibility). Biogas studies are directed towards methods used in improving biogas digester performance (stability) and gas production rate. Such methods include pretreatment, co-digestion, variation of operational parameters and use of additives (Oliveira *et al*., 2015, Battista *et al*., 2016, Hagos *et al*., 2017 and Bušić *et al*., 2018**).** Researches are now being focused on the use of additives for the optimization of methane gas production from smaller digesters (Nwokem *et al*., 2014). Most studies on the use of plant are biased towards using it as a co-substrate in co-digestion (Asikong *et al*., 2013, Safari *et al*., 2018) and only recently has plant in form of extract been used as additive. Biogas production can be improved by stimulating the microbial activities using various biological and chemical additives under different operating conditions. Additives are often used to provide the ideal nutrient condition for microbes. Therefore, the main objective of this research is to evaluate the production of methane as a constituent of biogas from tuber substrate and test for the effect of aqueous extracts of soya, neem and water hyacinth on methane gas yield.

MATERIALS/METHODS
Sample collection and preparation
Tuber peel which include, yam peel, cassava peel and potatoes (sweet and irish) was collected from Danmani area along western bye-pass of Kaduna metropolis, Kaduna state, Nigeria. The samples were washesd, air-dried, ground and stored in clean cellophane bags before use. All reagents used were of analytical grade.

Analytical Methods
The following parameters were determined: ash, moisture and

lipids contents by AOAC 2006 method; nitrogen by Kjedahl method; carbohydrate by Pearson 1976 method; total and volatile solids by APHA 2005 method. Trace metals composition was determined via Atomic Absorption Spectroscopy (AAS).

Biogas sample Analysis

Two litres pyrex digester bottles were used as digester systems and operated at mesophilic temperature. Two hundred grams (200 g) of the substrates were loaded into each of three (3) digesters and one litre of deionized water mixed with 100 cm^3, 300 cm^3 and 500 cm^3 respectively, of soya beans aqueous extract solution prepared using protocol described by Handa *et al.* 2008) was added into the three (3) digesters. The same procedure was repeated for neem and water hyacinth extracts. The digester bottles were covered with a bottle stopper with two holes to avoid air from getting into the digesters. One hole was used for the determination of temperature, and the other was connected to delivery tubing which was used to collect and measure the volume of biogas produced under water through the downward displacement method. The digesters were subjected to periodic agitation to ensure thorough mixing of the contents while maintaining intimate contact between the micro-organisms and the substrate to enhance the complete digestion of the substrate. The composition of the biogas produced was monitored using a biogas analyzer (IRCD4, China) on a daily basis.

Plate 1: Experimental Setup for Biogas Production.

VFA Determination

Volatile fatty acid (VFA) concentration was determined by transferring twenty (20 cm^3) of the samples from each digester and filtered into a 100 cm^3 beaker. Concentration of Volatile fatty acid (VFA) Using Kapp (1984) method and the filterates pH was determined by a pH meter.

$$\text{Sa (mg/L)} = \frac{131340 \text{ X M X VA}_{5-4\text{meas}}}{\text{VS}} - 3.08 \text{ X Alk}_{\text{meas}} - 25$$

Where;
Sa = Volatile Fatty Acid Concentration
M =Molarity
$VA_{5\text{-}4,\ measured}$ = Volume of acid required to titrate a sample from pH $_{5.0\text{-}4.0}$
$VA_{4.3,\ measured}$= Volume of acid required to titrate a sample at $pH_{4.3}$
VS =Volume of sample
Alk_{meas} = Measured alkalinity

$$\text{Alk}_{\text{meas}} = \frac{\text{VA}_{4.3\text{meas}} \text{ X M X1000}}{\text{VS}}$$

RESULTS AND DISCUSSIONS

The results of tuber peel biomass characterization showed that it is rich in carbohydrate with sugar content of approximately 70 %. High proportion of carbohydrate is known to yield much biogas as they are easily degraded by microbes (Russo *et al*., 2009). Volatile solid content was also high which show high biogas production potential. The trace heavy metals (Fe, Co, Ni and Mn) content was quite high, trace metals are very essential for methanogens as they are nutrients needed for their growth and activity if present within threshold (Sylwia *et al*., 2018). The high level of Fe recorded resulted in the high levels of CH_4 obtained in the digester systems. It has been reported that Fe is the most essential trace metal needed by the methanogens to support growth (Danmallam *et al*., 2020). The physico-chemical characteristics of tuber peel substrate are summarized in Table 1.

Table 1. The Average Physico-chemical Composition of Tuber Peel Substrate

PARAMETERS	TUBER PEEL
%Ash Content	4.803±0.271
% Moisture Content	5.883±0.047
% Volatile Solid	49.107±0.101
% Total Solid	94.867±0.137
% CHO	69.087±0.133
% N	1.987±0.050
C/N	35:1
Mg/kg Fe	74.75
Mg/kg Co	45.75
Mg/kg Ni	15.07
Mg/kg Mn	5.20

Fig. 1 shows percentage methane gas produced from tuber peels digester systems with and without the addition of plant extracts. The reactors with soya extract recorded 57, 61 and 63 % methane production, that of neem extract recorded 55, 63 and 67 % and water hyacinth recorded 59, 54 and 61 %. The value for methane production from tuber digester system without extract (control) recorded 42 %.

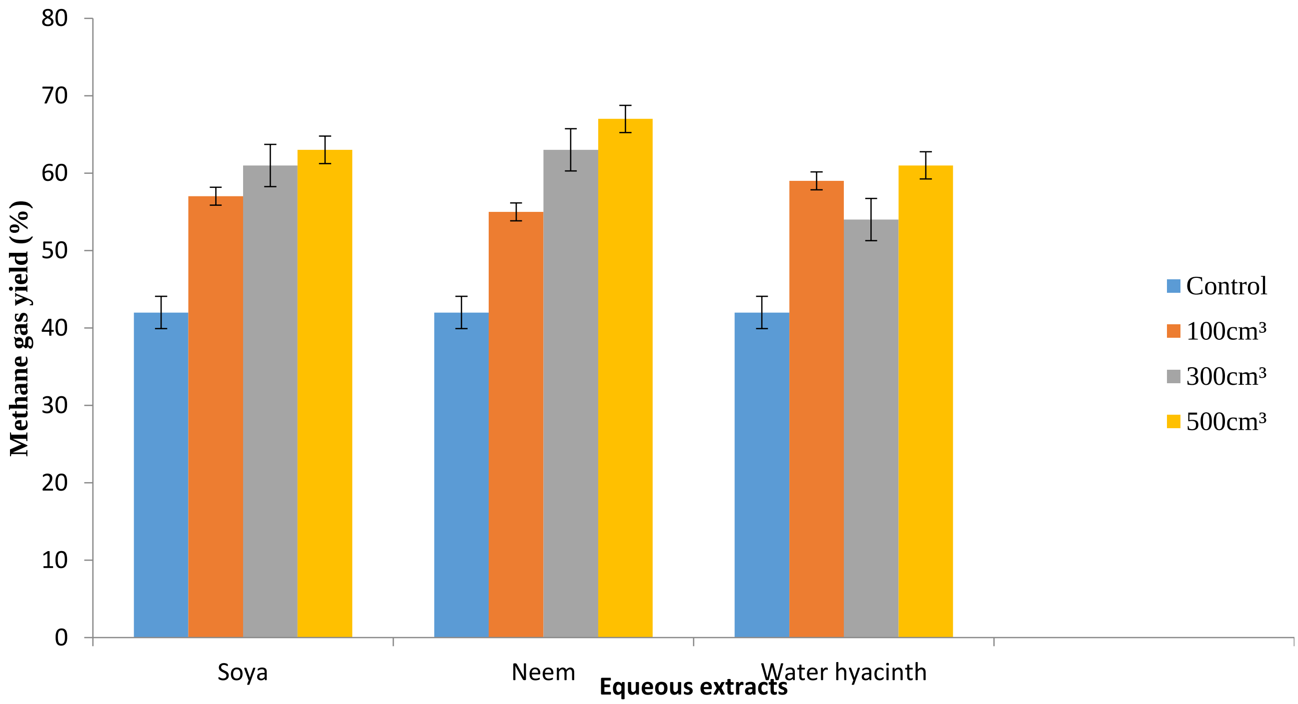

Figure 1: Methane gas yields of TU Digester Systems with aqueous extracts additive at different volumes

Depending on the extract and the volume added, an increase in methane production of 12 -25 % was recorded as presented in Figure 1. Organic additives make use of microorganisms (mostly bacteria and fungi) to degrade recalcitrant biomass for improved biogas production. They are said to maintain favorable conditions for increased gas production in anaerobic digestion by producing enzymes that are able to extensively degrade lignin and break down cellulose and hemicellulose resulting in increased biomass digestibility (Mutschlechner *et al*., 2015). Leaf extract synergistically improved the production by balancing acidogenesis and methanogenesis at high volumes which provides easily biodegradable organics to anaerobic consortium (Sang-Ryong *et al*., 2019) that accounted for higher CH_4 production observed in the digester systems of leaf extract additives.

Fig. 2 shows the volatile fatty acid (VFA) concentrations in the above reactors. The reactors with extract additives recorded lower VFA (561, 433 and 403 mg/L for soya, 507, 398 and 286 mg/L for neem and 632, 512 and 488 mg/L than the reactors without additives (985 mg/L).

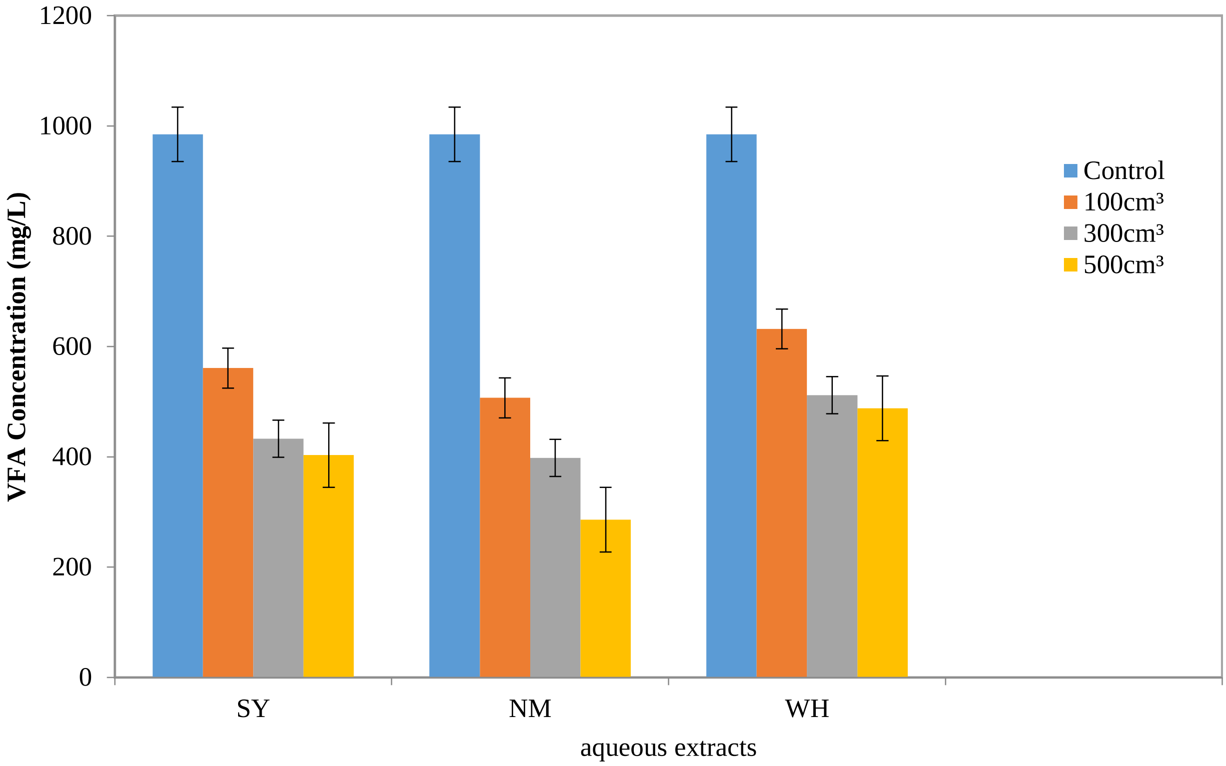

Figure 2: Volatile Fatty Acid Concentrations in TU Digester Systems with leaf aqueous extracts additive at different volumes

The varying performance of the digester systems seen in Figure 1 can be attributed to the volatile fatty acid concentration obtained from the digesters. Methane gas yield from anaerobic digester is dependent on VFA concentration of that digester, because if the rate at which volatile fatty acids (VFAs) produced especially acetic acid is greater than the rate at which it is used up by the aceticlastic methanogens during AD, then, this could lead to gradual decrease in pH which is unfavorable for biogas methane production (Bouallagui *et al*., 2009). Over-accumulation of volatile fatty acid beyond the regulatory threshold has the potential of inhibiting methanogenesis, thus disrupting the AD process (Franke *et al.,* 2014). The digester systems recorded very low concentration of VFA. In all the digesters, volatile fatty acid concentration was decreasing as the volume of leaf extract was increasing from 100 to 500 cm^3 (Figure 2) which led to higher methane gas yield in digesters with increased extract volumes. The pH for these digester systems were within optimum (Table 2). This was the reason for the significant improvement in methane yield from TU with plant extract addition up to 25 %.

Table 2: Effect of Plant aqueous extracts addition on pH for the Digester Systems

Week	Soya	Neem	Water hyacinth
1	6.09	6.13	5.87
3	6.68	6.42	6.13
5	7.21	7.14	6.85
7	6.47	6.28	6.31

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