

EVALUATION OF NUTRIENT POTENTIALS OF EFFLUENT FROM BIODIGESTION OF WATER WEED SPECIES AS SOIL AMMENDMENT

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ABSTRACT

The study assessed the nutrient potential of water weeds effluent from biogas production as soil amendment. Three species of water weeds [Duck weed (DW) (*Lemna minor*), morning glory (MG) (*Ipomea asarifolia*) and water hyacinth (WH) (*Eichhornia crassipes*)] were subjected to digestion in a batch type anaerobic digester. The water weeds were co-digested in a calculated mixture ratio (w/w dry Basis) of DW: WH (30:70, 50:50, 70:30, 100:0), MG: WH (30:70, 50:50, 70:30, 100:0) and WH (100%) and monitored for a retention period of 16 weeks. The raw water weeds and effluents from bio-digestion were analysed for plant nutrients (N, P, K, Ca, Mg and OC) and heavy metals (Mn, Pb, Cr, Ni, and As) using standard methods. The result showed positive significant effect of anaerobic digestion of water weeds on nutrient content, for example, 4.76% N and 9.05% N were obtained from raw DW and bio-digested effluent respectively. Similar trend was noticed for micronutrients. Significant reduction in heavy metal content was recorded after bio-digestion, Cd, Pb and Ni content in raw water weed were 1.62, 1.5 and 0.03 mg kg⁻¹ respectively while 0.09, 0.080 and 0.015 mg kg⁻¹ were obtained after bio-digestion. Among the different mixtures of water weeds, digestion of sole material gave higher values in major and minor nutrients compared with effluent from mixed water weeds. The study concluded that effluents from bio-digestion of water weeds are richer in plant nutrients than raw samples thus giving dual benefits: production of biogas and resulting effluent as fertilizer.

Key words: Effluent, Water weeds, Biogas, Organic matter, Soil amendment.

INTRODUCTION

Water weeds are those plants growing in water body and completing part or whole life cycle in water. They are challenging the ecological stability of freshwater bodies (Khanna *et al.*, 2011, Gichuki *et al.*, 2012), out-competing all other species growing in the vicinity thus posing a great threat to aquatic biodiversity (Patel, 2012). A lot of water system like ponds, lakes and irrigation canals suffer from over

population of invasive weeds either rooted or floating (Adanikin *et al.*, 2017). This can only be curtailed by adopting a useful and sustainable utilization strategy. One of the ways of managing or maintaining water system ecology is to harvest the water weeds and convert the biomass to organic fertilizer or for biogas production. Nigeria is facing a looming food security crisis with a growing population becoming increasingly dependent on imported foods. At the same time the once dominant

subsistence-oriented farm economy is at risk of gradual marginalization as a result of soil infertility. The use of industrially synthesized chemical fertilizer to amend soil fertility status (FAO, 2011) is becoming unsustainable and dangerous due to its adverse effect on the resource base as a result of frequent and excessive use. However, most Nigerian farmers lack basic knowledge of Soil Testing Programme, therefore, the risk of nutrient imbalance as a result of frequent use of chemical fertilizer has now become a great threat to the productive power of soil. Investigations by Lombin, (1983; 1985) revealed that Nigerian savannah soils are deficient in micronutrients whereas Mustapha and Loks (2005) attributed this to the use mineral fertilizers that supply only the major nutrients. There is therefore, need for a good and sustainable alternative to mineral fertilizer that could supply micronutrients. Previous studies showed that effluents from biogas are richer in plants nutrients than raw biomass due to microbial decomposition of the plant tissues to release more N (Ai *et al.*, 2006; Shi *et al.*, 2001; Shi *et al.*, 2002; Li *et al.*, 2006; Hao *et al.*, 2007). Wang *et al.*, (2008) reported positive influence of application of biogas effluent on soil structure, soil fertility, water retention capacity and permeability. Further reports (Li *et al.*, 2006, 2007) showed liming effects of some biogas effluent and significant increase in soil organic matter. In Nigeria, studies on the use of animal manure for biogas production and their effluents are good organic fertilizers, and it was observed that most major and micronutrients are present in appreciable amount thus; making them superior to mineral fertilizer (Hao *et al.*, 2007). The use of water weeds for biogas production and subsequent use of the

effluent as organic fertilizer is new in Nigeria. Despite the availability of water weeds, research information on using their effluents from biogas production as an alternative fertiliser for crop production in Nigeria is scanty. Therefore, this study examined the nutrient potential of effluent from bio-digestion of some water weeds as a viable soil amendment.

MATERIALS AND METHODS

Sources of Experimental Materials

Fresh water hyacinth (WH), duckweed (DW), morning glory (MG) and cow dung (CD) were used for the study. Water hyacinth was harvested from a lagoon located in Orile-Iganmu, Lagos, duckweed was harvested from an earthen fish pond located in Igboya, Ile-Ife, Osun-State, morning glory was harvested in a channel of Opa river located in Obafemi Awolowo University (OAU) campus in Ile-Ife, Osun-State and cow dung was collected from the Teaching and Research Farm, OAU, Ile-Ife, Osun-State.

Laboratory Analysis of Raw Water Weed Samples

Fresh samples of the water weed species (WH, DW, MG and CD) were oven dried at 75°C to constant weight. They were ground with porcelain mortar and piston to fine particle size and stored in plastic containers for analysis. Moisture content, N, P, K, organic carbon (OC), S, were determined: Moisture content was determined using oven-drying method at a temperature of 105 °C for 24 hours. The kjeldahl method (Bremner, 1996) was used for nitrogen content determination, organic carbon was determined after dry ashing at 550°C for 6hrs (Mercer and Rose, 1968) while determination of other elements: Mg, Ca,

Fe, Zn, Mn, Cd, Pb, Cr, Ni, Hg, and As were carried out by wet digestion using atomic absorption spectrophotometer (AOAC 2005).

Feedstock preparation

Fresh WH, DW, and MG on collection were chopped to small sizes (< 5 mm sieve size). The total solid content of each water weed used was 8% while water was 92% as recommended by Zenneaki *et al.* (1996). Cow dung slurry served as the liquid and culture medium for digestion and anaerobic microbes respectively. The weight of the cowdung used was 7.42 kg (dry basis) which made up to 60% of the digester volume.

The mixture ratios (w/w dry basis) digested were: DW:WH (30:70, 50:50, 70:30, 100:0), MG:WH (30:70, 50:50, 70:30, 100:0), while WH (100%) was used as reference sample for comparison with other treatments. The feedstocks were weighed into separate digester according to their different mixture ratios. Each mixture ratio was replicated three times and the digesters were hermetically sealed. The digestion was monitored for 16 weeks.

Nutrient and heavy metals Analysis in the effluents

Effluents samples were collected after the retention period, into specimen bottle through the digester drain plugs, labelled according to their treatments and the nutrients and heavy metals determined using atomic absorption spectrophotometer after wet digestion in 10 ml concentrated Nitric acid and 10 ml concentrated perchloric acid (AOAC 2005).

Statistical Analysis

The data obtained during the experiment were subjected to analysis of variance

(ANOVA) to assess treatment effects using statistical analysis system (SAS, 2000). Duncan's multiple range test was used to compare treatment means at 5% level of probability

RESULTS AND DISCUSSION

The result showing the essential nutrients and heavy metals content in the effluents from bio-digestion of water weeds and the raw samples were recorded in Tables 1 and 2. Bio-digestion had significant effect ($p < 0.05$) on the nutrient contents of the water weeds. Nitrogen (N) contents of raw DW and its effluent after bio-digestion were 4.76% N and 9.05% N respectively. Similar findings was reported by de Boer (2008). Peter and Stephen (2011) also reported 15% increase in N concentration in effluent than the raw water weed. Slight exceptions were observed with combination of different water weeds, for instance N content in effluent from the mixture of MG:WH (30:70), MG:WH (50:50) and DW:WH (30:70) were not significantly ($p > 0.05$) different from raw WH (Table 1). Effluent from sole digested WH had the highest N content (9.5%) likewise, effluent from sole DW had the highest P (8.55%), while effluent from sole MG had the highest K (5.23%) which was significantly ($p < 0.05$) higher than K in all the effluents and raw samples. Increase in P content of the effluent was due to degradation processes during anaerobic digestion which improved P plant availability (Loria and Sawyer, 2005 and Massé *et al.*, 2011). Effluent from sole WH, DW, and MG had the highest OC content 38.25%, 38.95% and 36.95%, respectively. These were significantly ($p < 0.05$) higher than values recorded for the raw samples.

Table 1: Nutrient Content of Effluents from Bio-digestion of Water Weeds

Sample Code	N (%)	P (%)	K (%)	OC (%)	S (%)	Ca (%)	Mg (%)	Fe		
								(mgkg ⁻¹)	Zn (mgkg ⁻¹)	Mn (mgkg ⁻¹)
Raw DW	5.75f	2.94f	0.75f	21.4g	0.35g	3.17b	0.48ed	7.4f	11.4h	7.2hi
Raw MG	6.7e	5.22d	0.85f	27.5def	0.45fg	4.1a	0.57bcd	6.96f	13.5gh	9.295def
Raw WH	7.4de	4.6de	1.45fe	26.6ef	0.5efg	2.805bc	0.6bcd	5.8f	15.8fg	8.96ef
MG:WH (30:70)	5.75f	3.695fe	1.395f	26.4f	0.585def	1.695e	0.455ed	11.4e	18.05f	9.06ef
MG:WH (50:50)	6.75e	3.9dfe	2.6cde	29.55d	0.725bcd	1.89de	0.52cde	13.175cde	22.95de	7.9gh
MG:WH (70:30)	8.05cd	5.1cde	3.5bc	34.5bc	0.84ab	2.2d	0.685abc	14.625bc	28.05b	10.05cd
MG:WH (100:0)	9.05ab	6.195bc	5.23a	36.95a	0.94a	2.695c	0.84a	17.15a	32.55a	10.95b
DW:WH (30:70)	7.6d	4.155def	1.775def	28.9de	0.495efg	1.665e	0.365e	11.49e	21.55e	6.85i
DW:WH (50:50)	8.4bc	6.37bc	2.695cd	33.65c	0.55ef	1.78de	0.445de	12.55de	24.3de	8.6fg
DW:WH (70:30)	8.8ab	7.45ab	2.89bcd	36.55ab	0.625cde	1.91de	0.535cd	14.3cd	27.4bc	9.675de
DW:WH (100:0)	9.085ab	8.55a	3.08bc	38.95a	0.75bcd	2.04de	0.61bcd	16.33ab	31.95a	10.85bc
WH (100)	9.5a	6.775b	3.93b	38.25a	0.75bc	1.735e	0.73ab	17.225a	24.75cd	12.7a

Means with the same letter in Columns are not statistically different at $p \leq 0.05$.

Effluents from sole digested water weed also had higher values for S compared to raw and mixed water weeds though slight improvement was noticed. Improved sulphur content recorded in effluent samples could help alleviate sulphur deficiency in soils of Southwestern Nigeria (Oseni *et al.*, 2017). The calcium (Ca) content in the effluent was lower compared with the raw samples. Raw DW and raw MG had the highest Ca content with 3.17%

and 4.1%, respectively and were significantly ($p < 0.05$) higher than the Ca contents in all the effluents. Similar result was reported by Marcato *et al.*, (2008) and has been attributed to the fact that Ca crystallize out as carbonates during bio-digestion. The mixture of MG:WH (100:0) had the highest magnesium (Mg) content (0.84%) which was not significantly different from MG:WH (70:30) and WH (100).

Table 2: Heavy Metals Content of Effluents from Bio-digester of Water Weeds

Sample Code	Cd (mg ⁻¹ kg)	Pb (mgkg ⁻¹)	Cr (mgkg ⁻¹)	Ni (mgkg ⁻¹)	As (mgkg ⁻¹)	Hg (mgkg ⁻¹)
Raw DW	1.3b	1.4b	0.38b	0.035ab	0.01cd	nd
Raw MG	1.7a	1.82a	0.435b	0.0325ab	0.015bc	nd
Raw WH	1.62ab	1.5b	0.6a	0.03abc	0.0255ab	nd
MG:WH (30:70)	0.11c	0.105c	0.105c	0.04a	0.025a	nd
MG:WH (50:50)	0.06c	0.045c	0.06c	0.03abc	0.01cd	nd
MG:WH (70:30)	0.06c	0.04c	0.035c	0.045a	0.015bc	nd
MG:WH (100:0)	0.04c	0.06c	0.02c	0.03abc	0.001d	nd
DW:WH (30:70)	0.095c	0.065c	0.04c	0.025abcd	0.02ab	nd
DW:WH (50:50)	0.09c	0.07c	0.04c	0.015bcd	0.0055cd	nd
DW:WH (70:30)	0.055c	0.035c	0.08c	0.01cd	0.001d	nd
DW:WH (100:0)	0.03c	0.02c	0.105c	0.0055d	0.001d	nd
WH (100)	0.09c	0.085c	0.035c	0.015bcd	0.01cd	nd

Means with the same letter in columns are not statistically different at $p \leq 0.05$.

nd, not detectable

[†] Critical values of trace elements in soil: Cd (2.0 mg kg⁻¹), Pb500(mg kg⁻¹), As (1500 mg kg⁻¹), Ni (100 mg kg⁻¹), Mn (2000 mg kg⁻¹), Cu (100 mg kg⁻¹) and Cr³⁺ (1500 mg kg⁻¹) (Podlesakova *et al.*, (2002))

It was observed that most major and micro plants nutrients are present in appreciable amount in the water weed effluent thus making them superior to mineral fertilizer that supplies majorly primary nutrient elements. This report agrees with previous studies (Callander and Barford, 1983a; 1983b; Jin and Chang, 2011) and was attributed to the fact that conditions during digestion influenced the chemical speciation of nutrients in liquid organic materials. Heavy metal contents (Cd, Pb and Cr) of effluents were significantly ($p < 0.05$) lower compared to the raw samples. Effluent from sole WH, DW and MG had the lowest values in heavy metals for example, effluent from bio-digestion DW alone had 97.7%, 98.5% and 72.4% reduction in Cd, Pb and Cr respectively compared to raw DW while 97.6%, 96.7% and 95.5% reduction in Cd, Pb and Cr

respectively were recorded with the effluent from bio-digestion of MG alone compared to raw MG. Similar trend was obtained with WH. Among the mixed water weed species, highest value in Cd (0.11 mg/kg), Pb (0.105 mg/kg) and Cr (0.105 mg/kg) was obtained from mixture of MG:WH (30:70) however, these were 91.5%, 92.5% and 72.4% lower than in the raw samples respectively. However, the heavy metals content recorded in both the raw water weed sample and their effluent are below the standard acceptable in some International countries (Nsikak *et al.* 2014). The amounts of nickel (Ni), arsenic (As) and mercury (Hg) were not detectable. Abii (2012) reported 19.40 and 102.0 mg kg⁻¹ for Cd and Pb respectively in Nigerian soils (0-15 cm depth) but the concentration decreases with depth, the values were significantly higher than critical limits in

some other international countries like Canada (0.5 and 25 mg kg⁻¹) Denmark (0.3 and 40 mg kg⁻¹), Ireland (10 and 50 mg kg⁻¹) and Netherland (0.8 and 85 mg kg⁻¹) for Cd and Pb respectively. Similarly, Podlesakova *et al.*, (2002) reported critical levels of trace elements in soils for Cd (2.0 mg kg⁻¹), Pb (500 mg kg⁻¹), As (1500 mg kg⁻¹), Ni (100 mg kg⁻¹), Mn (2000 mg kg⁻¹), Cu (100 mg kg⁻¹) and Cr³⁺ (1500 mg kg⁻¹).

CONCLUSION

The study showed significant improvement in the plant nutrient content of water weeds effluent as a result of anaerobic digestion. Significant reduction in heavy metal contents (Cd, Pb and Cr) was recorded thus giving dual benefits: Biogas production as a clean energy source for household and small scale industrial use and the resultant effluent as viable soil amendment. However agronomic efficiency must be carried out to support the research findings.

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