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Evaluation of Biogas Slurry as An Alternative Organic Fertilizer: A Case Study in Kenya

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Abstract

Chemical fertilizers have proven not to be the most appropriate solution to poor nutrient supply and poor soil structure in low input agricultural production systems especially in Kenya. There is need to explore alternative source of nutrients to be used by small scale farmers to enhance sustainable agriculture and also promote organic farming. Chemical analysis of biogas slurry (bio-slurry), to be evaluated as an alternative organic fertilizer was carried out and its nutritional composition compared to other organic fertilizers. Descriptive statistics on the results indicated that the mean percentage concentration of nitrogen, phosphorous and potassium were relatively high in bio-slurry as compared to slurry compost and farmyard manure at 2.14±0.6233, 1.37±0.888 and 0.70±0.3684 respectively. The findings from ANOVA indicated that there was a significant statistical difference in the nutritional composition of the bio-slurry with farmyard manure and slurry compost ($P<0.05$).The recommendations from this study will be used by agricultural laboratories in Kenya which do soil fertility advice to farmers to give guidance on the appropriate rate of application based on the estimated concentrations and also multipurpose benefits of the bio-slurry which is regarded as a waste to improve agricultural productions and soil structure.

Keywords: Bio-slurry, organic fertilizer, chemical fertilizer

Introduction

Agriculture sector is major contributor to economic development of Kenya and other third world countries. Chemical fertilizers have been used over long period to fulfil crop nutritional requirements but recently they are more expensive and sometimes not available when required during planting season. Their use has been associated with human health problems and environment degradation (Arisha and Bardisi, 2005).It has resulted to declining yield of the food crops in Kenya's food basket of western and north rift regions of the country due to degraded soils despite huge quantity of inorganic fertilizer application (Van den Bosch et al.,1998). Additionally, the demand for organic food production is increasing because of its ability to maintain health without the risk of synthetic enzymes and hormones, or other chemical effects on food. This situation demands exploration of other possible source of nutrients to the soil for supplementation. To improve agricultural productivity and soil fertility it requires Integrated Plant Nutrient Management (IPNM) System where chemical fertilizers, organic fertilizers, soil amendments, agronomic and other structural measures are used to conserve both water and soil. Among the many organic fertilizers, bio-slurry has not been effectively and efficiently utilized by many farmers in Kenya especially due to knowledge gap of not knowing the estimate nutritional composition of the bio-slurry and other potential benefits.

In recent years there has been an increasing interest in anaerobic digestion of farm and household residues in many parts of Kenya for biogas production especially through Kenya National Domestic Biogas Programme (KENDBIP) whose overall objective is to contribute to the achievement of the Sustainable Development Goals (SDGs) through the development of commercially viable, market oriented bio-

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gas sector and dissemination of domestic biogas plants in rural Kenya. This Programme has been implemented to many parts of the country by Kenya National Farmers Federation (KNFF).

Biogas production from agricultural biomass is of growing importance as it offers considerable environmental benefits and additional source of income for farmers (Amon et al., 2007). During anaerobic decomposition, 25-30% of the total dry dung of animal is converted into a combustible gas and a residue of 70-75% of the total solids content of the fresh dung comes out as sludge which is known as biogas slurry (Gurung B,1998).The bio-slurry generated from anaerobic decomposition of various organic matter is considered a good quality organic fertilizer (Islam,2006).The composition of bio-slurry depends upon several factors; the kind of dung (animal, human, or other feedstock), water, breeds and ages of the animals, types of feed and feeding rate. If urine is added, more nitrogen is added to the bio-slurry which can speed up the compost-making process. This improves the carbon/nitrogen (C/N) ratio in the compost. But this also depends on the kind of digester (Center for Energy studies, Institute of Engineering, 2001). The bio-slurry contains high percentage of readily available nutrients thus can be applied directly to plants either liquid or solid for basal or top dressing (Mikled et al.,1994).Proper utilization of the bio-slurry by farmers can supplement the use of chemical fertilizers in Kenya which will save the economy, (Yu et al.,2010; Abubaker, 2012).

Bio-slurry has a potential to provide considerable amount of both macro and micro nutrients which are easily available than composted manure and farmyard manure besides appreciable amount of organic matter (Ishikawa et al.,2006;-Kumar et al.,2016). The presence of available nitrogen in plants accelerates the growth cycle as the higher ammonium fraction of the bio-slurry is more easily accessible for the crops (Möller et al.,2008;Möller and Stinner, 2009).In bio-slurry, the C/N ratio of bio-slurry is lower than in FYM, which accelerates the nitrogen mineralization process. This in turn helps the uptake of nitrogen in the crops, but also increases ammonia emissions.FYM is oxidized to nitrate and nitrites, which do not bond well with soil particles and therefore leach out faster (Ghoneim, 2008).Compared to chemical fertilisers, bio-slurry decomposes with a slow process which is better for nutrient uptake and assimilation for plants (Yu et al., 2010).The total nitrogen concentration of FYM can be up to 30% lower than in biogas slurry (Möller et al., 2008).

The use of biogas slurry, a by-product from biogas digester, can provide a beneficial way for farmers, community, reduce burden on economy of a country and improve sustainability of agriculture because it's environmentally friendly and has no toxic effects. This embracement of biogas technology will ultimately lead to rural industrialization. Hence this study was carried out to evaluate the biogas-slurry as an alternative organic fertilizer at some counties in Kenya.

Materials and Methodology

Sampling

The samples were collected from Kajiado (-1° 51' 8.57" S, 36° 46' 36.59" E) Kiambu (1° 10' S, 36° 50' E) and Nakuru (0° 16' 59.99" N, 36° 04' 0.01" E)counties in Kenya between the months of April and December 2015 based on systematic-judgmental sampling method. A total of 90 samples were collected; 30 bio-slurry, 30 slurry compost and 30 farmyard manure samples. The bio-slurry sample was obtained by stirring the tank in circular motion, scooping the sample into the bucket, mixed and then taking 200mls as representative to the laboratory. Slurry compost as well as Farmyard manure samples were collected from 4-5 places from the middle of the heap, sampled separately in similar polyethylene bottle of 200ml capacity, mixed thorough to form homogenous composite, then a representative sample packed for transportation to the laboratory for analysis. The pH of the bio-slurry was measured within 24 hours after sampling.

Physical and chemical analysis

The chemical and physical analyses were carried at Kenya plant Health Inspectorate Service-Analytical Chemistry laboratory which is ISO 17025 accredited, using Standard Operating Procedures.

Analysis of Nitrogen

The concentration of nitrogen in the samples was determined by kjeldahl method. This method is divided into 3 stages, digestion, distillation and titration.

Digestion: Accurately weighed (0.5g) of the bio-slurry, farmyard manure and slurry compost, were digested using 10mls of concentrated sulphuric acid with a catalyst ,copper sulphate tablet at 3500C for two hours then transferred into 100ml volumetric flask.

Distillation: 5mls of the aliquot was steam distilled using 0.2g of heavy magnesium oxide to liberate Ammonium-Nitrogen, which was collected using Boric acid, after sometime the Nitrate-N was determined by adding Devardes alloy to the same sample, steam distilled and the ammonia collected using boric acid.

Titration: The amount of nitrogen was quantified by titration of the samples with 0.01N HCL by using mixed indicator of bromocresol green and methyl red till the colour changed to light pink. The titre values were added then used to compute percentage Total Nitrogen.

Analysis of Phosphorous

Phosphorous content was determined using UV-Visible spectrophotometer (Perkin-Elmer Lambda 25 model)

Table 1. NPK Composition of Bioslurry,slurry compost and farmyard manure on average from three counties

Sample type	%N (X±Sd)	%P (X±Sd)	%K(X±Sd)
Bio- slurry	2.142±0.623	1.367±0.888	0.701±0.368
Slurry compost	1.377±0.477	0.700±0.422	0.672±0.340
Farmyard Manure	0.666±0.368	0.486±0.506	0.618±0.444

X=mean,Sd=standard deviation

Table 2. Concentration of NPK in bio-gas slurry, slurry compost and farmyard manure from three different counties in Kenya

Region	Sample	Nitrogen (%)	Phosphorous (%)	Potassium (%)	pH
Kajiado	Bio-slurry	2.158±0.4734	0.859±0.51107	0.652±0.3102	7.84±0.51
	Slurry compost	1.659±0.4148	0.531±0.1638	0.609±0.2257	
	Farmyard manure	0.810±0.5425	0.384±0.1852	0.565±0.1567	
Kiambu	Bio-slurry	1.803±0.3415	1.352±0.4096	0.694±0.4734	8.00±0.45
	Slurry compost	1.038±0.2220	0.601±0.2702	0.669±0.3087	
	Farmyard manure	0.657±0.2312	0.401±0.2493	0.616±0.4245	
Nakuru	Bio-slurry	2.467±0.8159	1.891±1.2331	0.758±0.3326	7.95±0.44
	Slurry compost	1.432±0.5415	0.967±0.5932	0.736±0.4668	
	Farmyard manure	0.532±0.2176	0.6744±0.8191	0.672±0.6513	

by AOAC 978.01 method. Accurately weighed (0.5g) of bio-slurry, FYM and slurry compost were digested using 10mls of concentrated Nitric acid and 4mls of Per chloric acid at2000C for two hours, left to cool then transferred quantitatively through what man filter paper number 40 into 250ml volumetric flask. The colour complex for sample aliquots was developed by use of Ammonium Vanadate-Molybdate mixture and concentration determined at 430nm.

Analysis of Potassium, Calcium, Manganese, Magnesium, Copper, Iron and Zinc
Accurately weighed (0.5g) of bio-slurry, FYM and slurry compost were digested using 10mls of concentrated Nitric acid and 4mls of Per chloric acid at2000C for two hours, left to cool then transferred quantitatively through what man filter paper number 40 into 250ml volumetric flask. Potassium concentration was determined by flame emission spectroscopy at 766.5nm while Ca, Mg, Mn, Cu, Fe and Zn were analysed at 422.7nm, 285.2nm, 279.5nm, 324.8nm, 248.3 and 213.9nm respectively using Flame atomic absorption spectrophotometer.

Data analysis
Analytical results from bio-slurry, farmyard manure and slurry compost were compared using descriptive statistics and ANOVA.

Results and Discussion

The chemical composition of the biogas slurry farmyard manure and slurry compost were determined and compared statistically.Table 1 indicates that biogas slurry has highest nutritional composition of percentage NPK as compared to slurry compost and farmyard manure. Biogas slurry can be used as highly valuable, nutritious and environmentally friendly alternative organic fertilizer. This study supports this argument. The nutritional composition of the bio-slurry differ depending on the species,age,condition of the animal, composition of the diet, type of digester , the way the slurry is stored, treated and applied to the field and also environmental factors which are associated with geographical areas as shown in Table 2. This can be attributed to different climatic conditions in these regions, species and age of the animals and variation of diet of the animals involved. From ANOVA test, the bio-slurry samples from Kajiado, Kiambu and Nakuru sampling sites have significantly high levels of Nitrogen (P=0.000) as compared to slurry compost and farmyard manure Table 3 .This variation can be explained by the fact that during anaerobic decomposition of the cow dung and other animal wastes, the organic wastes are converted to ammonium nitrogen through mineralization which is readily available to the plant (Gurung,1977) hence high nitrogen percentage. Some farmers store the bio-slurry in open places, making it dry, as it dries ammonium nitrogen is volatized to the environment leading to low nitrogen levels, this accounts for relatively low nitrogen levels in slurry compost as compared to bio-slurry. From previous studies by Khandeiwal, it was noted that maximum benefits are obtained when the slurry is used fresh in liquid form from the biogas digester, (Khandeiwal, 1986). The levels of potassium and phosphorous are equally relatively high as compared to those of slurry compost and farmyard manure. Phosphorous is statistically significantly high in bio-slurry (P=0.000) at 95% confidence interval as compared to slurry compost and farmyard manure whereas there is no significant difference in potassium concentrations as shown in (Table 5).This study supports the finding by Netherlands Development Organization (SNV, 2011) that shows that bio-slurry is a superior organic fertilizer to farmyard manure and slurry compost. Similar findings were found from laboratory analysis carried at center for Environment Science and Climate resilence; India (Shakeel,2014).The findings of percentage nutritional composition of bio-slurry are similar with those of Myles et al.,1993. With these known high nutritional composition of the bio-slurry as compared to other organic fertilizer, it will enable researchers and extension agents to design spatially explicit and appropriate recommendations to farmers. If the bio-slurry is integrated well with chemical fertilizers at appropriate combination, it will lead to increased crop yield, quality produce like shapes and size and nutrient enhancement in the produce and ultimately reduce cost of farming through reduced dependence on expensive mineral fertilizer (Karki and Gurung, 1996; Jeptoo et al., 2012, Shakeel, 2014), Additionally it can be

Table 3. ANOVA test for percentage Nitrogen

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6.504	2	3.252	78.860	0.000
Within Groups	3.588	87	0 .041		
Total	10.092	89			

Table 4. ANOVA test for percentage phosphorous

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.398	2	1.699	20.36	0.000
Within Groups	7.257	87	0.083		
Total	10.655	89			

Table 5. ANOVA test for percentage Potassium

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.079	2	0.040	0.707	0.496
Within Groups	4.872	87	0.056		
Total	4.951	89			

used as a bio-chemical pesticide to inhibit disease (Liu et al., 2008).

The pH of the bio-slurry samples on average was alkaline, as shown in Table 2.Application of this bio-slurry to farms will provide a buffering effect to the soil and act as a remediation to most acidic soils in most parts of Kenya protecting the crops from aluminium toxicity. The alkaline bio-slurry pH is mainly attributed to the formation of ammonium carbonate and removal of carbon dioxide as a result of the transformation of $CO_3^{(2-)}$ and$2H^+$ to carbon dioxide and water,(Webb and Hawkers,1985;Georgacakis et al.,1982;Sommer and Husted,1995).

Due to relatively high levels of nutrients in bio-slurry, it could be the best organic fertilizer to rejuvenate soils since it's a rich source of both plant nutrients and organic matter. The slurry constitutes good quality manure free from weed seeds, foul smell and pathogens and it contains full range of micro and macro nutrients which are essentials to plants (Newar, 2008). Their appropriate use can lead to reduction of the use of chemical fertilizers, this will benefit farmers in cost cutting and soil environment will be highly fertile and at productive state. Most of macro and micro nutrients present in the three sample matrices met the standards set by Kenyan body for standards, Kenya Bureau of standards (KEBS) for organic fertilisers as per table 6 above. Farmyard manure was found to have high levels of calcium; Magnesium, Manganese and Zinc as compared to bio-slurry and slurry compost, some of the high levels of these nutrients are attributed to animal feed supplementation to prevent mineral deficiency in animals. The availability of these nutrients at appropriate levels is advantageous for full development of the plants as they are up taken by plants a from the soil after application as either biogas slurry, slurry compost of farmyard manure.

Conclusions

With this study, it can be conclude that biogas slurry has high levels of nutrients as compared to other organic fertilizers .With a standardized formulation and known range of concentrations, it can be used as an environmentally friendly fertilizer to increase yields, buffer acidic soils through its liming characteristics, improve soils structure and with integrated plant nutrition system, it can reduce the use of chemical fertilizers by 50%.Embracing biogas technology in rural areas in developing countries such as Kenya it will lead

Table 6. Average Macro and micro nutrients in biogas slurry, slurry compost and farmyard manure

	Ca(%)	Mg(%)	Mn (Mg/kg)	Fe (%)	Cu(Mg/kg)	Zn(Mg/kg)
Biogas slurry	0.44	0.09	152.72	0.13	514.22	140.59
Slurry compost	1.80	0.26	766.11	1.35	290.23	324.32
Farmyard manure	2.93	0.44	811.40	0.99	136.63	238.23
KS2290:2011	1.0 (Min)	0.50 (min)	-	0.1 (min)	300ppm (Max)	-

KS2290:2011 –Kenyan standards for materials regarded as organic fertilizers.

to rural industrialization since there are multiple benefits associated with it, a part from the methane gas which is a major focus.

The findings of this study can be used by agricultural based institutions in Kenya which carries soil analysis to help them guide farmers on the appropriate rates of application depending the fertility status of their soils when doing soil recommendations.

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Conflict of interests
The authors declare that they have no competing interests.

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